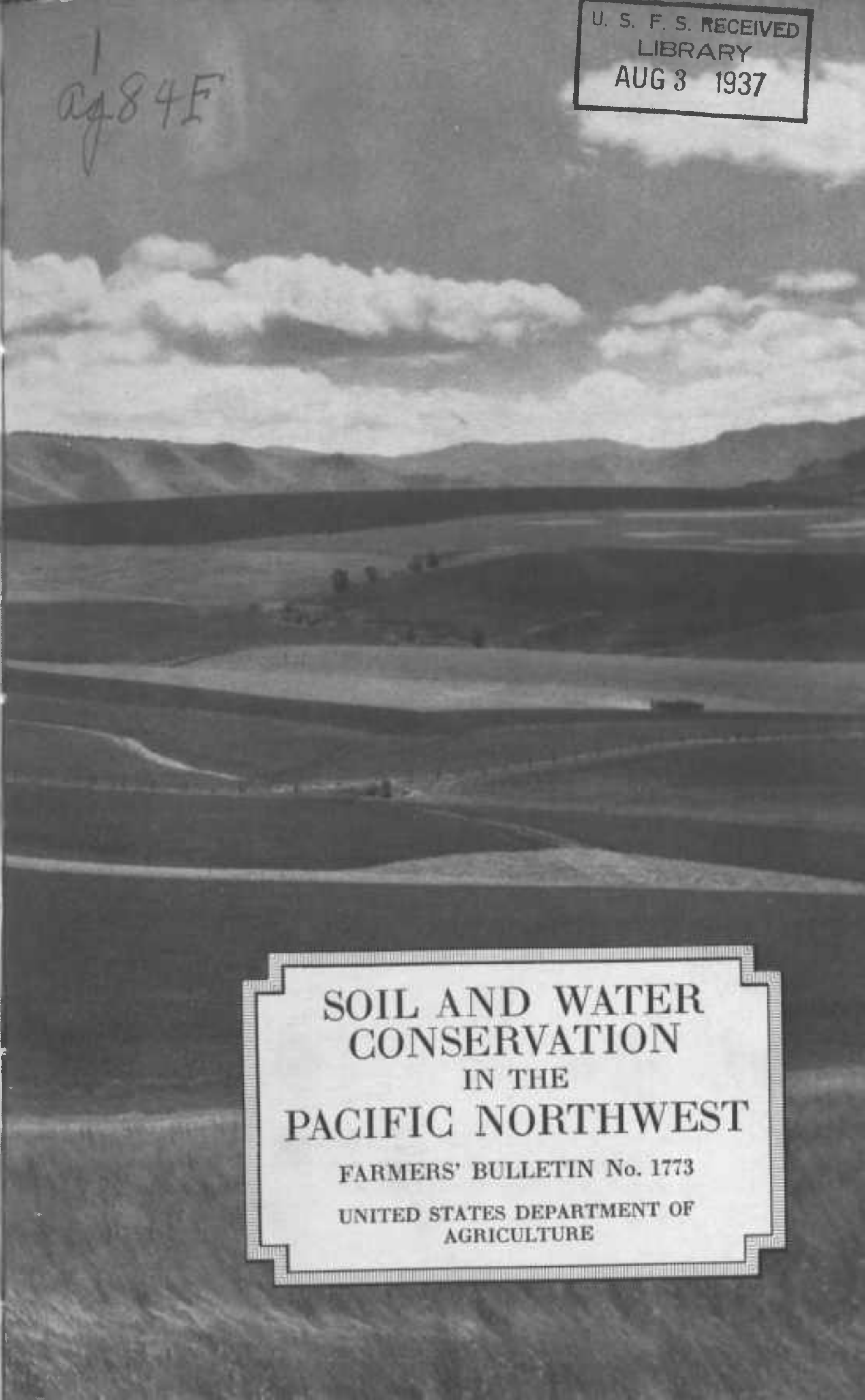


SOIL AND WATER CONSERVATION IN THE PACIFIC NORTHWEST

FARMERS' BULLETIN No. 1773

UNITED STATES DEPARTMENT OF AGRICULTURE

FIGURE 1.—*Under natural conditions soils are protected from the erosive action of wind and water by a cover of vegetation. Practically all of those parts of the Pacific Northwest that were not forested were covered, 60 years ago, with bunchgrasses.*

Yesterday in the Northwest

"THE BUNCH GRASS rippled in the breeze like a field of ripe grain, reaching to our saddle stirrups", wrote one of the earliest of pioneers to cross the Rockies and see the Palouse prairie of the Pacific Northwest. Nearly every early account of the men and women who made the journey mentions vast pastures of bunchgrass. Some called it "a natural hay."

Sixty years ago bunchgrasses covered practically all of those parts of the Pacific Northwest that were not forested (fig. 1). Wheatgrasses, fescues, so-called "bluegrasses", and wild-ryes were the principal grass species, intermixed with a variety of other plants, both annuals and perennials. In the sags where the water table was close to the surface there were small patches of shrubby vegetation, mainly thornbush, wild rose, chokecherry, and gooseberry.

The terrain is rolling, and in places steeply sloped, but the pioneers, farmers and ranchers alike, affirm that there were no gullies on the hillsides nor deeply entrenched drainage channels in the alluvial bottoms. There was no evidence anywhere of destructive soil erosion on land covered by vegetation. The valley bottoms were broad with indistinct drainage channels coursing through the deep alluvium which, through the centuries, had accumulated in the lower lying levels.

Since the pioneers nosed the first plows into the prairie soils not so many years ago, the original bunchgrass vegetation has largely disappeared. Only vestiges of it survive. Patches of vigorously growing bunchgrasses may still be seen in fence corners, along roadsides and railroads, in cemeteries, and on ranges moderately grazed. The bunchgrass pictured in figure 2 is growing within the city limits of Spokane. Until recently, a 1,600-acre remnant of the native plant cover could be seen on the Johnson estate in the heart of the Palouse, but this field was plowed in 1935. The contrast between this newly plowed field and the fields surrounding it is striking. The nearby wheatlands are scarred by gullies, and the mantle of topsoil is but half as deep as that on the newly turned prairie field.

The contrast between the early appearance of the range of the Pacific Northwest and the appearance of the range a few decades later is described by Russell, who visited southwestern Idaho and southeastern Oregon for the United States Geological Survey 35 years ago. Russell, a geologist and trained observer, wrote

FIGURE 2.—*Only vestiges of the original bunchgrass cover survive; in fence corners, along roadsides and railroads, in cemeteries, and on ranges moderately grazed. This patch is growing within the city limits of Spokane.*

in United States Geological Survey Bulletin 217, Notes on the Geology of southwestern Idaho and southeastern Oregon, pages 19–20:

Before man disturbed the balance of natural conditions, many of the valleys of Idaho and Oregon became deeply filled with fine, usually yellowish or nearly white rock débris, and only faint stream channels, if any at all, could be distinguished on the surfaces of the deposits during the seasons of extreme desiccation. The uplands and valleys alike were clothed with an open growth of vegetation, consisting largely of bunch grass. On the uplands and hillsides the grasses served to bind the soil together, but less completely and efficiently than is usually the case in humid regions where a continuous sod is present. In the valleys, owing to the absence in many instances of stream channels in the deep alluvium, soil moisture was held near the surface during a considerable part of the dry season, and grasses, notably the coarse rye grass, grew luxuriantly. This delicate balancing of conditions, a result of a long period of adjustment, was seriously disturbed when stock was introduced and grazing on the natural pastures was carried on extensively. * * * [This] resulted in the nearly complete destruction of the bunch grass over vast areas, and in consequence the surface run-off from the uplands has been rendered more rapid, and rills have been formed where previously the rain water soaked into the ground and percolated slowly away. The more rapid surface run-off has caused the hillsides to be deeply gullied, much of the soil has been swept into the lowlands, and on account of the increased strength of the surface streams the débris taken in suspension and redeposited is coarser as well as more abundant than formerly. Destructive denudation is thus in process on the hillsides and an equally destructive deposition is taking place in the valleys. Owing to overgrazing, the grasses do not have an opportunity to mature their seeds and scarcely to sprout from the old roots, and the destruction of the natural pastures is thus

for several reasons going on at an accelerated rate. One result of the quicker transfer of the surface waters from the upland to the valleys is the excavation of channels, frequently from 5 to 20 feet deep, in valley floors, where previous to the change referred to, the water spread out over the surface and deposited fine silt instead of eroding as at present. The cutting of channels has, in many instances, resulted in a far more complete subdrainage of the valleys, and in consequence has caused the disappearance of the rye grass which formerly flourished in them and its replacement by sagebrush.

The Cover Held the Soil

Under natural conditions soils are protected from the erosive action of wind and water by a cover of vegetation. The foliage breaks the force of the fall of the raindrops, which splash, trickle, or mist to the ground. The moisture is absorbed by a soil mat of vegetable material which, like a sponge, takes up several times its own weight in water. Water is released slowly from this vegetable debris and seeps into the soil through crevices, tunnels, and passages opened by the action of roots, frosts, animal life, and plant decay. During drenching rains it flows slowly away impeded by each stem, each blade of grass, each bit of residue from plants. Flowing slowly and quietly, water picks up little soil and in passing between the stems and through the leaf residue carries only the very smallest particles in suspension.

The soil itself, under thick vegetation, is held in place by plant roots. The fibrous roots of bunchgrasses, for example, penetrate downward into the soil 40 to 60 inches and spread outward 15 to 30 inches. Plants 3 inches in diameter at the crown send out 250 to 400 fine fibrous roots which describe a network throughout the soil they occupy (fig. 3). In addition, the total length of the short rootlets is about three times the total length of the main roots. Some roots die each year, adding organic matter to the soil and providing small passages for water to enter.

The Pacific Northwest must have lain under the protection of grass and forests for thousands of years while the topsoil accumulated to a depth of 7 to 15 inches; for soils form slowly. Topsoil is formed at an almost unbelievably slow rate. It has been estimated that with many types of land 400 to 1,000 years or more are required by nature to build 1 inch of topsoil. During this process of soil formation under a plant cover some movement of surface material by washing and blowing occurs, but the rate of loss is usually so slow that soil is built from the material beneath more rapidly than it is removed from the surface. This slow movement of soil under undisturbed conditions is called geological or normal erosion, and is a step in the series of normal processes by which the surface of the earth is molded and remolded through the ages.

Soil losses, however, have accelerated and multiplied since men have put the land to new uses. Normal geological erosion has given way to abnormal land-destroying erosion. These abnormal losses began with the destruction of the protective grass and forest cover. The vegetation has been removed or seriously depleted on millions of acres by cultivation, overgrazing, fire, and logging. As a

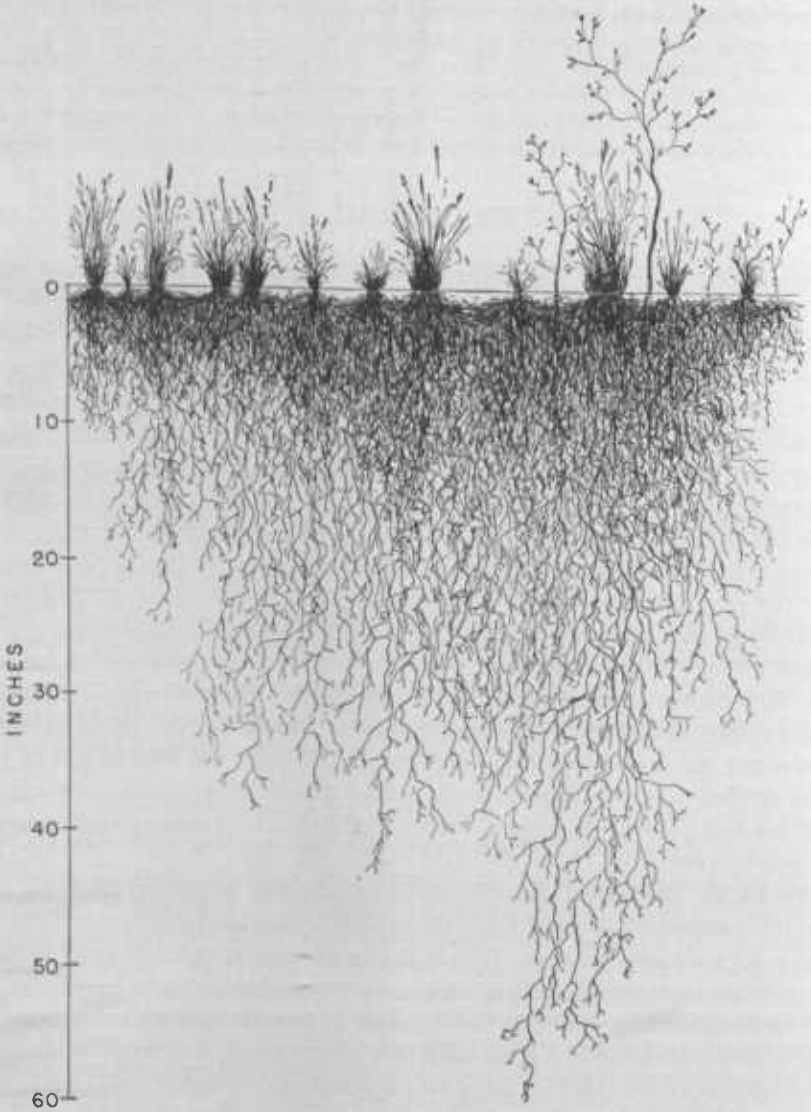


FIGURE 3.—*The soil, in virgin condition, is held in place by plant roots. The fibrous roots of bunchgrasses penetrate downward into the soil 40 to 60 inches. Plants 3 inches in diameter at the crown send out 250 to 400 fine fibrous roots. About a fourth of the roots are shown in this actual cross section. (Drawing furnished by Forest Service and University of Idaho.)*

result, soil is being lost from tilled fields, overgrazed ranges, and burned-over lands at an alarming rate, a rate many times faster than it is formed by natural processes.

The rapidity with which soil is lost under cultivation in the Northwest is being measured in a series of plots at the erosion experiment station at Pullman, Wash. The soil at the station is Palouse silt loam. Each of a series of plots on a 30-percent slope is protected by steel guards from intake of water from above or from the sides. Run-off and soil are caught in steel tanks and measured.

During the 4-year period from 1932 to 1935, soil losses were equivalent to about 8.52 tons an acre each year from the plot in winter-wheat and summer-fallow sequence, even though crop residues were carefully utilized for erosion control. On the plot bare of vegetation or crop residues, the soil loss was equivalent to about 27.82 tons an acre each year. The plot in grass, however, lost soil at the rate of only 1.45 tons an acre, and most of this washed from the plot during the first year of the seeding before the grass was fairly established. At these rates of loss, 6 inches of topsoil will wash from the bare-soil plot in about 37 years; from the plot in winter wheat and summer fallow with crop residues utilized, in approximately 117 years; and from the plot in grass, in about 700 years.

The plot in grass lost 3.71 percent of the rainfall in run-off in the 4 years; the winter-wheat and summer-fallow plot lost 9.3 percent of the precipitation; and the bare plot lost 25.03 percent. The average annual rainfall at Pullman is 20.7 inches.

Measured Soil Losses

An inventory of land conditions in the Northwest was completed by the Soil Conservation Service in 1934. In that year a crew of trained men made a survey of erosion conditions in the region. Both crop and grazing lands were carefully inspected.

Losses From Tilled Land

According to the 1930 census, there are in the Pacific Northwest 18,384,000 acres of cultivated land, including about 5,557,000 acres of irrigated land. About 6,192,000 acres lie in the subhumid zone and are subject chiefly to erosion by water; 6,635,000 acres in the semiarid zone are subject to erosion by wind and water.

The survey revealed that approximately 36 percent of the agricultural land in the intermountain zone of the Pacific Northwest is subject to severe blowing. An additional 11 percent of the total agricultural land in this zone was designated as slightly eroded by wind; this land, about 2 million acres, has drifted only moderately and can still be protected against serious damage from wind. It can be placed upon a permanent agricultural basis if erosion-control measures are quickly and efficiently applied and properly planned methods of farming are followed.

146615°—37——2

The general survey indicates further that about 4,500,000 acres in the semi-arid areas have been damaged by wind and water erosion to the point that much of it was retired from cash-crop production after a series of dry years and low crop prices; doubtless other areas will soon be retired.

Some 6 million acres of water-eroded croplands in the intermountain zone have, on the average, lost about half of the original topsoil. This surface soil, of course, has not been removed as a uniform layer. It has been entirely removed along with some subsoil in parts of fields, partially removed in others. Some of it has been redeposited on lower lying lands. As a result, subsoil farming is practiced on some of the land, while in many instances the richer, more fertile lowlands are being damaged by depositions of silt (fig. 4). About 197,000 of the 6,000,000 acres have become essentially worthless for wheat production.

FIGURE 4.—*Six million acres of water-eroded croplands in the Pacific Northwest have lost, on an average, about half of their original mantle of topsoil. Fertile lowlands are being further damaged by depositions of silt from surrounding eroded slopes.*

Careful classification of irrigated lands according to degree of erosion is yet to be made. It is known, however, that such lands are subject to erosion, in some instances severe erosion, the degree depending on the soil type and its management, slope, the way in which irrigation water is handled, and the crop grown. Irrigated lands are also affected indirectly by erosion, by the silting of irrigation reservoirs with soil from the watersheds that feed them. In some instances, silting has been rapid and is materially reducing storage capacity.

West of the Cascade Mountains in Washington and Oregon there are approximately 5 million acres of agricultural land. Of this amount, about 3 million acres may be classed as moderately rolling to hilly. These rolling and hilly lands are subject to erosion where clean-cultivated or intertilled crops are grown. Much of this land is intensively cultivated, and its valuation is high.

Erosion on the Range

There are about 58 million acres of open range land within the States of Idaho, Washington, and Oregon. From approximately 3 million of these 58 million acres wind and water have either removed the mantle of topsoil or worn it so thin that the higher types of forage plants do not grow (fig. 5). About 7

FIGURE 5.—*From approximately 3 million of the 58 million acres of range land in the Northwest, wind and water either have removed the mantle of topsoil or have worn it so thin that higher types of forage plants cannot grow.*

million acres, while less seriously damaged, are so badly depleted of topsoil that it is doubtful that, even under the best possible management, they can soon be restored to as much as half their original grazing capacity. The remainder of the range land, about 48 million acres, displays various lesser stages of erosion; but it is still possible, fortunately, to restore it to within perhaps four-fifths of its original grazing capacity by immediate and continuous application of conservation practices.

Erosion in Forests

The forested lands of the Pacific Northwest have fared better. It is estimated that less than 10 percent of the 45 million acres in the intermountain zone is severely eroded. This 10 percent includes areas that have been repeatedly subjected to burning. Nearly 45 percent of these lands is protected by vegetation sufficiently to prevent serious water run-off and erosion. The cover on an equal area has been reduced by grazing, fire, and logging, resulting in a run-off of water which has caused moderate and sometimes serious erosion on local areas. There is no accelerated erosion on three-fourths of the forested land west of the Cascades, and only a very small area of the total west slope is severely eroded.

Forests under the care of the Forest Service generally exhibit little destructive erosion except where fire or excessive grazing, before they became part of the national forests, destroyed the cover (fig. 6).

FIGURE 6.—*Forests exhibit little or no destructive erosion except where fire or excessive grazing has destroyed the cover.*

The Clean Summer Fallow[1]

Of all the farming practices that contribute to loss of soil from cultivated fields in the Northwest, the clean summer-fallow system is plainly the principal offender. When wheat was first grown in the Northwest, farmers did not summer-fallow their land, for the areas first broken by the plow were those

[1] "Clean summer fallow" is here contrasted with "trashy summer fallow", in which careful use is made of crop residues and stubble to decrease soil blowing and washing.

most favored by rainfall. The newly turned, rich, mellow soils produced a crop each year. Yields at first were so large, in fact, that new standards of production were set. When these soils were first turned, comparatively little rain water flowed over the surfaces of fields; most of it, frequently all of it, soaked into the ground. Consequently, little topsoil was carried away by escaping waters. This happy condition obtained for about a dozen years, with yields gradually declining as the organic material in the soil was used up by decay. In time it was found that certain necessary plant nutrients were not available in adequate amounts. Finally farmers, worried about their yields, resorted to the summer-fallow system of farming and rested their fields 1 year in 3 or 4. Later, as the supply of organic material was further reduced under the clean summer-fallow system, farmers grew but one crop in 2 years, thus establishing the widespread

FIGURE 7.—*In areas of greater rainfall the summer-fallow system contributes heavily to soil washing, particularly when the soil enters the winter finely pulverized and nearly saturated with water.*

practice of fallowing fields in alternate years. From this time forward, blowing and washing of soil became increasingly noticeable in fields improperly managed under the fallow system.

The primary purpose of the summer fallow where there is less than 15 inches of rainfall in the Northwest is to store moisture in the soil for use by the growing crop in the succeeding year. A second purpose is to keep the soil moist during the spring and summer, when nitrate-forming bacteria are most active. Nitrogen, an essential element in plant nutrition, is found in many soils chiefly in organic matter; and it is released for plant use only by natural processes of decay. Decay

speeds up during that part of the fallow year when the soil is warm and moist, and as a result nitrates are released and become available for the use of growing plants.

But in areas receiving more than about 15 inches of rainfall, summer-fallow tillage is practiced primarily to make plant food available. Tests in these areas reveal that there is sufficient moisture to grow a crop satisfactorily each year, provided nitrogen is available in adequate amount. In these areas of greater rainfall the clean-fallow system contributes heavily to accelerated soil losses (fig. 7). The fallowed surface soil frequently enters the winter nearly saturated with moisture, in unfit condition to take up water freely from melting snows and spring rains. A second cause of erosion in clean-fallowed fields is surface "sealing" or puddling. When the surface soil becomes depleted of organic material, small particles of soil are carried into the soil pores, which clog them and impede or prevent moisture penetration. Consequently, water that is unable to penetrate flows over the surface, carrying a soil load in suspension. Cropped soils, on the other hand, usually enter the winter with a covering of stubble and generally are sufficiently lacking in moisture in the fall to absorb all or most of the precipitation during the rainy season.

FIGURE 8.—*From thousands of acres of land in the Pacific Northwest winds have blown a full plow layer of soil during their brief agricultural history.*

If proper farming practices are pursued, summer fallow in alternate years appears, on the whole, to be unnecessary in much of the Northwest having more than about 15 inches of rainfall. This area extends from Spokane, Wash., through Moscow and Grangeville, Idaho, and Dayton and Walla Walla, Wash., to Pendleton, Oreg., where the summer-fallow system has been responsible for the loss

of approximately one-fourth of the year's precipitation and critical amounts of soil.

On heavier soils where the precipitation is from 10 to 15 inches annually and good farming practices are followed, the soil-washing problem is less noticeable, although of importance. As yet, wind erosion is serious only in certain localities on these heavier soils. But on the sandier lands of central Washington, northern Oregon, and southern Idaho, clean-fallow land blows, frequently quite badly. Winds, while possibly no stronger than those of previous decades, cause more drifting of the soil than formerly because clean-fallow tillage and loss of organic matter have modified the structure of the soil, and the soil, becoming less cohesive, offers less resistance to wind.

The outstanding causes of wind erosion in the Pacific Northwest are the reduction in the content of organic matter in the soil, burning or close grazing of stubble and straw, plowing stubble completely under, and excessive tillage of summer-fallow lands. The dust mulch resulting from these practices makes the soil especially susceptible to wind erosion. Picture such a summer-fallow field struck suddenly by a windstorm. In a few hours the entire plowed layer of soil, 5 to 7 inches deep, may be swept away. On some farms this loss has been repeated several times. From thousands of acres of land in the Pacific Northwest winds have blown away a full plow layer of soil during their brief agricultural history (fig. 8).

In Defense of Croplands

IT IS CLEARLY established that soils charged with organic matter seldom wash or blow as badly as soils that contain only small quantities. Decaying organic matter, generally referred to as humus, acts as a stabilizing material that enables one particle of soil to adhere to or clutch another. Organic matter, when decomposed, greatly improves the mechanical condition of soil. It opens the soil to easier penetration by roots and air. It promotes the formation of a desirable crumblike structure which makes heavier soils more friable and porous and enables them to take up, distribute, and hold water in a way favoring availability to plants. In sandy soils, humus links the soil particles one to another, enhancing soil water-holding capacity and minimizing leaching and erosion. Tests have shown that soils high in organic matter frequently contain 15 to 30 percent more granules than those low in organic matter and that the granules are about three times more stable with respect to resistance to erosion. It has also been shown that some soils originally high in organic matter erode more rapidly after the humus becomes depleted than soils originally deficient in organic matter.

Loss of humus from topsoils greatly changes their physical structure. Generally speaking, those soils that are washing or blowing badly, including the soils of the range, are those now most deficient in humus. The granules of these soils have broken down into separate particles, making the soil looser or more powdery, so that during dry seasons the detached grains are readily caught up by the wind. The heavier, fine-textured soils, when wet, are much more inclined to seal over and resist penetration by water than the coarse-grained types, and, so, to wash more rapidly.

To be successful, a long-time program of soil conservation for the Pacific Northwest must help to improve the topsoils. Improvement can be accomplished only by recharging the soil with organic matter derived from vegetation grown on the land. The success of such a program appears to depend in a large measure upon the introduction of soil-building crops into a rotation; on turning under crops of green manure; and on careful utilization of residues from harvested crops. Badly washed or badly blowing fields, further, must be retired to crops that will permanently cover the land, making abundant use of native grasses, cultivated grasses, alfalfa, and trees and shrubs.

Rebuilding a soil, once much of it is lost, is a slow process; it cannot be done in a year, nor in a decade, although by the application of various conservation measures the condition of the soil that remains may be gradually improved. Some precautions must be taken, however, to prevent the soil from washing away while this improvement is being effected. To this end, a number of mechanical measures will aid in holding the soil temporarily. Among these are timely and proper tillage with implements that leave the surface of the soil in a rough, cloddy, and trashy condition; contour tillage and contour furrows, and building dams of various kinds in gullies.

Experiments and common experience have proved the worth of a number of erosion-control practices. These measures have been applied in a series of demonstration projects located in typical farming areas throughout the Northwest. In these soil- and water-conservation projects, which extend over whole watersheds of 25,000 to 100,000 acres, farmers have entered into cooperative working agreements with the Soil Conservation Service of the United States Department of Agriculture. They have agreed to follow the farming recommendations of the Service for a period of at least 5 years in order to demonstrate thoroughly the various measures of erosion control. The measures of erosion control and water conservation described in the following pages may be seen on these watershed projects. They are located at Pullman, Pomeroy, Dayton, Walla Walla, and Goldendale, Wash., Worley, Moscow, Genessee, and Emmett, Idaho, and Athena, Heppner, Condon, and Moro, Oreg. Their locations are shown in figure 9 in the center of this bulletin, pages 28 and 29.

Soil-Building Rotations

To control erosion effectively a cropping system must provide a cover of growing vegetation or a vegetal litter for the land as much of the time as possible during the critical wet-weather months; it must supply organic matter to the soil, and it must help to improve, or at least to maintain, the productive capacity of the soil. Most of the cropping systems generally in use in the past in the intermountain zone of the Pacific Northwest failed to meet these requirements.

Most of the precipitation in this area falls between October and May. During the greater part of this period, a large proportion of the croplands, under the prevailing systems of farming, lie without the protection of a cover of vegetation and consequently wash badly. For example, when the Soil Conservation Service selected the watershed of the South Fork of the Palouse River for a soil- and water-conservation project, a survey disclosed that none of the major cropping systems provided sufficient cover for the land during the winter. Fifty-five percent of the cultivated land was cropped to winter wheat and then fallowed; 25 percent was in winter wheat, pea, summer-fallow rotation; 10 percent was

146615°—37——3

FIGURE 10.—*Soils charged with organic matter seldom wash or blow as badly as soils that contain only small quantities. One way to add organic matter to the soil is to plow under a crop of sweetclover such as that shown growing on the hilltop.*

in wheat followed by peas, and 7 percent was in a rotation of winter wheat followed by spring grain and summer fallow. Prior to 1934 only 1,100 of more than 100,000 acres had grown a green-manure crop—about 1 percent.

None of these cropping systems returned an adequate amount of organic matter to the soil, because as a rule the wheat stubble was burned and the residue from the pea crop was either burned or removed. Obviously these systems impoverish and deplete the soil in several ways. They remove more plant nutrients than they return; they deprive the soil of organic matter; they tend to puddle the soil; and they expose the topsoil to the forces of erosion throughout the winter.

Growing a legume crop in rotation with winter and spring wheat has proved an effective means of decreasing erosion in the subhumid areas (fig. 10). It has frequently been observed that land which has grown alfalfa for several years does not wash or erode as badly when plowed and sown to wheat as adjacent land farmed by the wheat-fallow system. Similar observations have been made of the effect of sweetclover and other legumes, especially when plowed under for green manure.

In the watershed of the South Fork of the Palouse River, different soil-building and soil-stabilizing rotations have been introduced. These provide for sweetclover on the land for 2 years in a 4- to 6-year rotation. They are listed in table 1.

TABLE 1.—*Typical soil-conserving rotations for wheat and pea farms*

First year	Second year	Third year	Fourth year	Fifth year	Sixth year
Sweetclover [1].	Sweetclover [2].	Winter wheat.	Peas.........	Winter wheat.	
Sweetclover and grass.	Sweetclover and grass.[3]	Spring grain...	.....do.......	.....do.......	
Sweetclover [1].	Sweetclover [2].	Winter wheat.	Spring grain...	....	
Do.[1].....	.....do.[2]......	Peas.........	Winter wheat.	Peas.........	Winter wheat.

[1] Peas may or may not be used as a companion crop.
[2] Sweetclover plowed under in early summer.
[3] Sweetclover used as pasture and plowed in the fall.

In the light of present knowledge, sweetclover appears to be the crop best adapted to reconditioning the soil in the more humid wheatland areas of the Northwest. A legume, it is capable of gathering nitrogen from the air during its growth. This nitrogen is turned back into the soil when the sweetclover is plowed under for green manure. Its extensive taproot system penetrates deeply into the relatively stiff clay subsoil. Sweetclover grows on poor clay hills, it fits easily into the present farming system, and the seed is cheap and easily obtainable. Turned under, it supplies abundant organic matter. Yields of grain crops following green-manuring with sweetclover, although occasionally depressed in the first year, are consistently higher over a period of years in areas of higher rainfall. Records of wheat yields kept by a farmer in the Dayton, Wash., soil- and water-conservation project, for example, gave an advantage of 58 percent in favor of land in sweetclover-wheat rotation over similar land seeded to wheat following summer fallow. From 500 acres seeded to sweetclover in 1934 and turned under in 1935, the wheat yield was 37.6 bushels an acre in 1936. About 2,000 acres of comparable land produced 22 bushels an acre in 1936, following summer fallow.

Sweetclover also provides fine pasturage. A farmer at Moscow, Idaho, in the Palouse conservation project, seeded 193 acres to a mixture of sweetclover and slender wheatgrass as a soil-conservation measure in 1934. That fall he pastured a band of sheep on the new seeding. In the following year the 193-acre field supported 300 cattle for 3 months, 75 for 4 months, and 115 for 3 weeks, all Herefords. The cows gained 2⅔ pounds a day and the steers 2 pounds. The total average gain was slightly over 400 pounds of beef an acre. Only two of the cattle were lost from bloat, which is a smaller loss than is normally expected on the open range.

Sweetclover or sweetclover-grass mixtures are not seeded with a companion crop on the poorer soils in the first cycle of the rotation in conservation project areas. On the better soils peas as a companion crop are proving satisfactory. The use of spring wheat, oats, or barley as a companion crop with sweetclover has proved hazardous. After the second or third cycle of the rotation, as the soils become improved, perhaps other nurse crops may prove acceptable.

A number of rotations are on trial in the more humid areas of the Northwest Wheat Belt. These require from 5 to 8 years to complete a cycle. In all of them, a legume crop plays the key role; a well-grown green-manure crop such as sweetclover supplies not only the material required for humus formation, but also supplies the nitrogen that makes it possible for the plant to make strong growth. On land most subject to erosion—the worn land and the steeper slopes—the rotation may consist of not more than two or three cash crops, followed by a mixture of alfalfa and grass for a number of years. On slopes of lesser degree, a sweetclover rotation may be used in which cash crops appear more frequently, whereas on land subject to little erosion—the flatter, foothill fields—the proportion of cash crops may be further increased. The rotation, in a word, is fitted to the field, not the field to the rotation.

In farming areas where the rainfall is too limited for success with alfalfa or sweetclover, another type of rotation is employed on the conservation watersheds. Steep, eroded slopes and wind-damaged fields are seeded to grass and retired from wheat production, for control of erosion; but on the better, more productive lands, a long-time dry-land grass rotation may be employed. On the Moro, Oreg., conservation project, for example, the rotation consists of grass for 5 to 7 years, followed by wheat and summer fallow for 5 to 10 years, depending on the type of soil and the degree of erosion. In selecting mixtures of grasses to use, an attempt is made to approximate the original vegetation. At Moro, for instance, crested wheatgrass is seeded in mixture with a smaller grass such as Idaho fescue or one of the dry-land bluegrasses, to thicken the cover. A little alfalfa seed of a hardy strain is included in the mixture. Some alfalfa plants will grow and survive even under these conditions. One legume plant to the square rod, even, is considered helpful in improving the quality of the forage, and a few plants of the legume will supply some nitrogen and help to stimulate the growth of the grass, thereby building up both the nitrogen and organic content of the soil more rapidly than if grass were seeded alone. Under certain favorable weather and soil conditions it is possible to obtain stands of grass with a light admixture of legumes, such as alfalfa or sweetclover, sown at rates of 1 to 3 pounds of the legume seed per acre. In some instances legumes sown with grass in this manner do not last more than 2 or 3 years, but their beneficial effect on the soil probably more than repays the cost.

Seeding grasses sometimes aggravates erosion if the seedbed is not properly prepared. In Gilliam County, Oreg., for example, a 700-acre field blew badly following seeding in an unprotected seedbed. In this instance the seeding was made on a finely pulverized summer-fallow field. Experience in the conservation projects indicates there is less danger from blowing when the seed is planted in a trashy seedbed prepared following a wheat or rye crop, or when the seed is planted in the fall directly in the stubble. Fall seeding of grasses, however, has been successful only in portions of the Pacific Northwest.

The value of perennial grasses for improving the soil structure cannot be overemphasized. The soil-binding qualities of perennial grass roots are unequaled, and grasses are without peer in improving soil tilth, opening the soil to great depth to the beneficial effects of moisture and air. Most research workers are agreed that the control of wind erosion on these lands can be effected only by persistent use of fibrous-rooted grasses in long-time rotations. The fact that the originally fertile prairie soils were built under a grass cover supports their contention.

Grass rotations are limited in the low-rainfall belt, of course, to fields that have not lost too much topsoil. Marginal or submarginal cultivated lands, of which there is a large acreage in the Northwest, must sooner or later be retired from cultivation and devoted to new uses.

New Uses for Worn Land

Erosion seldom removes the soil from all parts of a field evenly. Frequently, part of a field may lose all of its topsoil while the remainder of the field still may be highly productive. In such instances the eroding area frequently endangers the less damaged land. Outstanding examples in the Northwest are the clay hilltops of the Palouse country, the steeper slopes of the Blue Mountain foot-

FIGURE 11.—*Steep north slopes and clay hilltops are retired from wheat production and seeded to a mixture of alfalfa and grass, in demonstration projects in areas of higher rainfall. Although poorly adapted to wheat, because erosion with this crop is excessive, these areas produce good forage crops without serious loss of soil.*

hills, and the "blow" spots in areas of limited precipitation. The rich topsoil either is all washed or blown away or so much of it is lost that cash-crop farming is carried on only at a loss.

As long as the clay hilltops and steep north slopes of the Palouse are used to grow wheat they will endanger the richer, more productive parts of fields on lower lands. These clay hilltops have been stripped of their topsoil and can no longer absorb moisture readily. Nor does snow remain on them. Prevailing southwest winds tend to cause the snow to drift to the leeward side of these hilltops where it accumulates. Warm Chinook winds melt the snow quickly in the spring, and the land below is deluged with water. Water thus suddenly released from snowbanks cuts valuable fields with gullies, which interfere with tillage and harvesting operations. Once a field is deeply gullied, contour cultivation cannot be practiced, and machinery must be hauled up and down the slope. Running drill rows up and down hill provokes destructive erosion.

In its demonstration projects the Soil Conservation Service induces cooperating farmers to seed hilltops and steep north slopes permanently to forage crops, which, owing to their close-growing nature and soil-binding properties, deter water flow and effectively resist soil washing (fig. 11). The plant cover holds the snow where it falls, lessening drifting and effecting a more uniform distribution of moisture over the field.

Alfalfa and Grass Seedings

The permanent seeding that is proving most popular with farmers in the Palouse is a mixture of alfalfa and adapted grasses. This is a new type of seeding for the Northwest, where alfalfa, when formerly grown, was seeded in pure stand. At first the practice met with objections; farmers preferred to feed straight alfalfa. But after feeding for a season most farmers came to favor mixed hay, reporting that stock relished it. Greater yields over a period of years may be expected from the mixture, for as the stand of alfalfa gradually thins, perennial grasses fill in the bare spots. In pure seedings a less desirable annual grass, such as cheat, usually invades these bare spots in the stand.

Mixtures are greatly superior to pure seedings from the standpoint of erosion control. The grass fills the voids between the alfalfa plants, providing a more continuous sodlike cover. The combination of strong alfalfa taproots and fibrous surface-soil root systems of grass offers more effective resistance to soil washing and opens the soil to a greater depth for water penetration.

Owing to severe erosion on the steeper slopes of the Blue Mountain foothills, much of this land is withdrawn from wheat production either permanently or for long periods, in the conservation projects. Some of the longer slopes are badly gullied. Slopes above 30 percent, which from the standpoint of reducing run-off and permanency of agriculture cannot be used safely for growing wheat, are withdrawn from customary cash-crop production and seeded to alfalfa-grass mixtures.

On some of the less severely eroded steeper hillsides a long-time rotation of 6 years of an alfalfa and grass mixture followed by 2 years of cash crops probably will control erosion. Erosion-control treatment for slopes under 20 or 30 percent is special tillage, mixing straw with the surface soil, and sweetclover rotation; but when they are severely eroded, even moderate slopes are withdrawn from continuous cash cropping.

In the lower Columbia area many fields of shallow soil are broken by rock outcrops and deposits of gravelly material. Since these fields are uneconomical units for wheat production, they are being retired to grass and alfalfa in the conservation projects.

Grass Seedings

Areas severely damaged by wind erosion in the Columbia Basin dry lands are a constant threat to better agricultural lands. Once an area begins blowing, it expands rapidly. For the safety of the good agricultural lands nearby, if for no other reason, such areas should be seeded to grass and withdrawn permanently from the production of wheat. Many of these lands should never have been broken by the plow. As a rule such land, while unfitted for cropping purposes, is suited to controlled grazing once grass again covers it. Most of it lies adjacent to grazing land and may be handled as part of the range.

Tree Plantings

The farm plans in the working agreements between farmers and the Service, in conservation projects, frequently call for the planting of trees. On nearly every farm in the Palouse district, for example, some trees are planted on steep north slopes, on hilltops, or in out-of-the-way corners of fields. The purposes of the plantings are several. Where the rainfall is 15 inches or more a year, as in the Palouse, a profitable return in posts, poles, and small timbers may be expected from land and labor if the right tree species are selected and care is given them during the first years after planting. And once planted and established, such areas are safe from further erosion; practically all of the moisture that falls in a wood lot penetrates into the soil. Wood lots and shelter plantings (windbreaks) lessen snow drifting and soil blowing by breaking currents of wind. They provide shelter for stock and protect buildings from cold. In addition, tree plantings furnish cover for game and insect-eating birds and add to the charm of the farm home (fig. 12).

A planting of black locust on a clay hilltop at the Soil Conservation Service Experimental Farm near Pullman, Wash., held, entirely within its boundaries, from 4 to 5 feet of snow during the winter of 1936–37. Similar adjacent areas unprotected by hilltop plantings were bare of snow. The snow had blown from the hilltops into drifts on the north slopes. In melting, the drifts caused many shallow and occasionally deep soil slips. Snow within the planting

melting slowly caused no soil loss. Moisture tests taken immediately after the snow had melted showed that moisture had penetrated to a depth of between 7 and 8 feet within the black locust planting. Moisture had penetrated to a depth of only 2 feet on similar sites not planted to trees.

About 25 years ago the school of forestry at the University of Idaho, at Moscow, Idaho, planted a large variety of trees. Some 115 species now are growing in the university arboretum. These early plantings enable one to determine which trees are suitable for planting under similar conditions in the Pacific Northwest. Western white pine has done remarkably well. This is

FIGURE 12.—*Wood lots and shelterbelts lessen snow drifting and soil blowing by breaking currents of wind. They also provide shelter for stock and a source of extra income and add to the charm of the farm home.*

the pine which furnishes a large part of the annual lumber cut in the Northwest. Other species that have grown well are the Norway spruce, black locust, ponderosa pine, European larch, white fir, and red oak. A planting of black locust produced fence posts in 8 years on good soil.

Many plantings of black walnut are scattered throughout areas of light rainfall in Washington, Oregon, and Idaho. Trees set in deep soil on bottom lands, a natural site for black walnut, have grown well and produced good crops of large nuts. Walnut trees planted in shallow soil on steep slopes have made fairly good growth; but they are rather spindly, and the nuts are of low quality.

The department of forestry and range management at Washington State College at Pullman has distributed trees to farmers for 15 years. As a result

there are many plantings throughout the State that show which species grow best on various sites. Some Chinese elm from the original importation by the Bureau of Plant Industry were planted at Lind by the Washington Agricultural Experiment Station about 20 years ago. These trees have made good growth and are well formed. The annual rainfall is about 8 inches. Seedlings from the parent trees have done well when planted elsewhere in areas of low rainfall. A hedge of Russian-olive also was set out on the station grounds. This hedge has been trimmed regularly and after 20 years is in vigorous condition. Other species which have grown under these dry conditions are lodgepole pine, Scotch pine, Austrian pine, and ponderosa pine.

Near Ritzville, Wash., in an area having 9 inches of rainfall, a demonstration windbreak recently was established, consisting of ponderosa pine, Norway spruce, black locust, Russian-olive, and caragana. The trees are making excellent growth under cultivation.

That planted trees are a money-making as well as a soil-saving farm crop is illustrated by the planting on the Suckstorf farm at Spangle, Wash. About 10 acres of this 600-acre farm were planted to trees under the timber culture law of 1873. About 1895 the elder Mr. Suckstorf planted a variety of species recommended by the Division of Forestry of the United States Department of Agriculture. Some species were very successful. Foresters recently measured all the trees on a tenth-acre sample in a stand of Douglas fir and European larch. On an acre basis, they counted 570 trees; 240 trees had been cut in the last 10 years for fuel and farm timber. This planting is on a moderate northeast slope in Palouse soil. The planting was well cultivated for a few years, but no care has since been given it except to exclude farm animals. Needles and twigs cover the ground to a depth of several inches, an ideal cover for erosion control. The trees, many of them 60 to 84 feet tall and straight and upright, are from 4 to 14 inches in diameter.

On the McCroskey farm 1 mile east of Steptoe, Wash., is a 25-year-old planting. Some of the species which have been successful are Scotch pine, Norway spruce, blue spruce, western white pine, Austrian pine, Norway maple, and black locust.

Six years ago a shelter planting was established on the Pendleton farm of the Oregon Agricultural Experiment Station. The rainfall there is about 13 inches annually. The trees, Chinese elm, black locust, ponderosa pine, and maritime pine, have made a remarkable growth. A landscaped garden lies within the protected area. It is improbable that some of the species of shrubs and flowers in this garden would grow without the protection of the trees.

At another Oregon field station, at Moro, caragana, Russian-olive, ponderosa pine, and Chinese elm have been successful.

Wherever wind causes erosion on irrigated lands the planting of windbreaks is highly desirable. One of the most satisfactory combinations is caragana, Russian-olive, Norway spruce, and blue spruce.

146615°—37——4

FIGURE 13.—*Slopes planted to trees in demonstration districts are contour furrowed. The moisture caught by the furrows may mean, on drier sites, the difference between success and failure.*

A better record of survival and stronger growth may be expected from trees planted in contour furrows. When properly constructed, contour furrows hold water while the trees are growing. The moisture they catch may mean, on drier sites, the difference between success and failure. Some of the slopes planted to trees in the conservation-project areas of the Soil Conservation Service are contour furrowed (fig. 13).

Mixing Crop Residues in the Soil

Mixing all or a part of the residue from the harvested crop with the surface soil is one practice that may be applied universally as a measure for erosion control throughout the Pacific Northwest Wheat Belt (fig. 14). By means of this practice a supply of crude vegetable matter is built up, which constitutes a step toward providing decomposed organic matter and humus for improving the physical condition of the soil. But the practice is of even greater importance in the immediate control of erosion.

Wheat straw when mixed in the surface soil offers considerable mechanical resistance to erosion. Straw, roots, and crop trash protruding above the surface interfere with the lifting force of the wind and during rainy periods impede the flow of water. More important still, a trashy surface helps to prevent puddling —the sealing of the soil to water—and thus greatly reduces run-off and erosion.

For many years it was the general practice in the Northwest either to graze off all of the wheat stubble or to burn it. There were a number of reasons for

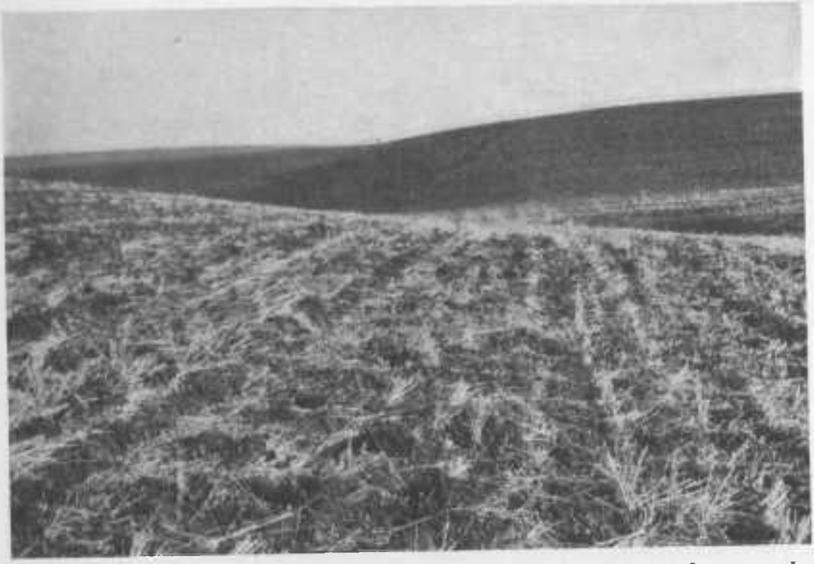


FIGURE 14.—*Mixing all or a part of the residue from the harvested crop with the surface soil is one practice that may be used universally as a measure for erosion control throughout the Pacific Northwest Wheat Belt.*

the rise of this practice. (1) In some of the wheat farming-range areas there is a shortage of winter feed. (2) With the tillage implements at hand when wheat farming first became a major industry in the Northwest it was difficult to handle crop residues satisfactorily. (3) Under certain conditions, turning under wheat straw may depress yields, particularly the first time it is done, if the job is not done properly. Turning under straw continuously appears to cause no important depression in yield if coordinated with a proven crop-rotation program.

The straw-scattering attachment now available for the combine makes it much easier to utilize crop residues for soil protection. This attachment, which sells for about $50, distributes the straw evenly across the swath (fig. 15); without it a combine, as used in the past, concentrated the straw in windrows or dumps, and unless it was burned, it got in the way of tillage operations. Fortunately, the newer tillage implements that are becoming popular in the Northwest are designed to handle crop residues in such a way that straw and pea vines may be conserved for incorporation with the topsoil.

Turning under a heavy growth of crop residues, especially cereal grain straw, with the ordinary moldboard plow sometimes depresses yields. This implement, which turns the furrow slice completely over, deposits a layer of straw at the bottom of the furrow where conditions are not favorable for the bacterial action necessary for decomposition. The straw, which remains until the next plowing incompletely decomposed at the bottom of the furrow, acts as a layer

FIGURE 15.—*A straw-scattering attachment on the combine distributes straw evenly across the swath and makes possible full utilization of crop residues without difficulty.*

of insulation and breaks soil continuity. Decomposition is more rapid near the surface of the soil, as the moisture and temperature conditions are more favorable.

Soil-Saving Tillage

Twenty or thirty years ago, when much of the Northwest had only recently been broken for wheat, the farmers who fallowed cleanest and tilled oftenest harvested the largest yields. The soils, newly broken, were still rich in organic matter and could be vigorously tilled without becoming thoroughly pulverized. But soils deficient in organic matter, as most Northwest soils now are, cannot be frequently tilled with ill-chosen implements without becoming pulverized and subject to rapid erosion by wind and water.

Experiences of farmers in conservation projects prove that much loss of soil can be avoided by timely tillage with implements which leave the surface of the soil cloddy and mixed with crop residues. The principle of successful tillage in dry-farming areas is to make and preserve clods rather than to crush and destroy them. To this end successful farmers employ implements having a lifting and sifting action. These implements mix the crop trash with the surface soil and leave some of it exposed. The use of such implements as the spike-tooth and drag harrow, which pulverize the soil, is avoided. The choice of tillage practices

to be employed will be governed mainly by the implements at hand, the density of the straw, the abundance of Russian-thistles, and seasonal conditions.

Stubble is left standing over winter, to be grazed moderately if necessary. The presence of the stubble through the winter greatly lessens snowdrifting. Tests reveal that the immediate effect is to promote deeper penetration of moisture. In the spring a one-way disk is commonly used for the first operation. This implement, if it is not operated too deeply, mixes stubble, weeds, and other trash with the surface soil. When the amount of trash is light a duckfoot cultivator may be used for the first operation. This tool leaves the soil ridged and the trash on the surface. However, the duckfoot does not operate well in dense straw, and its use in the first operation is usually restricted to land that does not produce more than about 10 bushels of wheat an acre. Nor can the duckfoot be used in fields infested with fork-branched weeds.

FIGURE 16.—*Straw or other crop residues may be mixed with the surface soil by using the large one-way disk for the first tillage operation. Disks 10 inches apart and 26 inches in diameter do good work.*

Fallow land is given a first tillage in the spring, when the soil is moist, with a one-way disk, duckfoot cultivator, or similar implement of lifting and sifting action. Later, after the clods have partly dried and have become set, a revolving rod weeder is run over the field once or twice, but seldom more than three times, a season. If winter wheat is not sown that fall, a spring-tooth harrow or other implement with lifting and sifting action is run over the field in the spring before the spring wheat is seeded.

In areas of higher rainfall, where from 20 to 40 bushels of wheat an acre are produced on an average, the stubble is incorporated in the topsoil by using the

large one-way disk (fig. 16). Disks 10 inches apart and 26 inches in diameter do good work. On heavy soils or on farms where the one-way disk cannot be used, owing to lack of power or steepness of slope, modified or abbreviated moldboard plows may be used to handle crop residues. In these plows, the moldboard is shortened, or sometimes removed, so that the furrow is not turned all the way over.

This kind of a tillage program requires, of course, seeding with a type of drill which cuts through trash, such as a single-disk or double-disk drill.

The chisel is sometimes used for the control of erosion. It leaves the surface of the soil open and in a cloddy condition. Unfortunately, there is little in the way of experimental data on which to base recommendations for its use. Its use after peas appears to be especially desirable because with this crop there is little trash to turn under for soil protection, and a cloddy surface must be depended on to stop excessive run-off over winter. Observation of results in the Service's soil- and water-conservation areas indicates that the practice may not be so well suited to wheat stubble where there is a heavy growth of straw. The chisel is best adapted to heavier soils and to areas where plow pans or clay pans have developed. When used for erosion control, the chisels are set to run 10 to 12 inches deep, whereas in subsoiling operations they are set at a depth of 16 to 24 inches.

Spring Wheat for Winter Wheat

During the months between October and April each year there usually comes a period of excessive run-off that causes heavy soil losses throughout the Wheat Belt of the Northwest. In 1932, for example, such a period occurred in January and again in March. In 1933 great losses occurred in December. It is during this winter period that the soil must be protected if erosion-control measures are to be effective.

The vegetative erosion controls that have proved most effective at the erosion experiment station at Pullman are wheat stubble, grass, alfalfa, sweetclover, sweetclover-grass mixtures, and alfalfa-grass mixtures. Winter wheat afforded inadequate protection against erosion. Even in years when wheat got an early start, growth was not sufficient to control erosion effectively. Land that is seeded to winter wheat enters the winter in a vulnerable condition, for the preparation of the seedbed pulverizes the clods of soil. On the other hand, land that is to be seeded to spring wheat may be carried through the winter with a rough, cloddy surface, protected further by a layer of trash—in a fit condition, in short, to absorb water. A shift from winter wheat to spring wheat is one promising means of avoiding heavy soil losses during the winter in areas where spring wheat can be grown profitably (fig. 17).

In the Blue Mountain area peas for canning are grown in rotation with wheat. This practice permits the elimination of the early-plowed summer fallow and

FIGURE 17.—*A shift from winter to spring wheat is one promising means of avoiding heavy soil losses in some areas. Land that is planted to winter wheat enters the winter in a vulnerable condition, for the preparation of the seedbed pulverizes the clods of soil. This field, here shown planted to spring wheat, was carried through the winter with a cloddy, trashy surface, in fit condition to absorb water.*

greatly reduces erosion and run-off when the pea land is plowed or chiseled after harvest and left in a rough condition over winter for seeding to spring wheat. These benefits are lost, however, when the pea land is worked down in the fall and seeded to winter wheat. Seeding spring wheat after peas not only reduced erosion but also produced higher average yields than fall seeding in experiments at the Pendleton, Oreg., field station.

Healing Gullies

Comparatively little cropland in the Pacific Northwest has been abandoned, as yet, as a direct consequence of gullying. The most serious erosion losses result from run-off water stripping away topsoil in thin sheets. Gullies, however, exact a heavy toll. They break great fields into patches. They jar heavy machinery and cause repair bills to run up. They delay operations. They waste power, forcing farmers to till up and down hill rather than around the hill. They drain fields and whole bottoms excessively, curtailing yields.

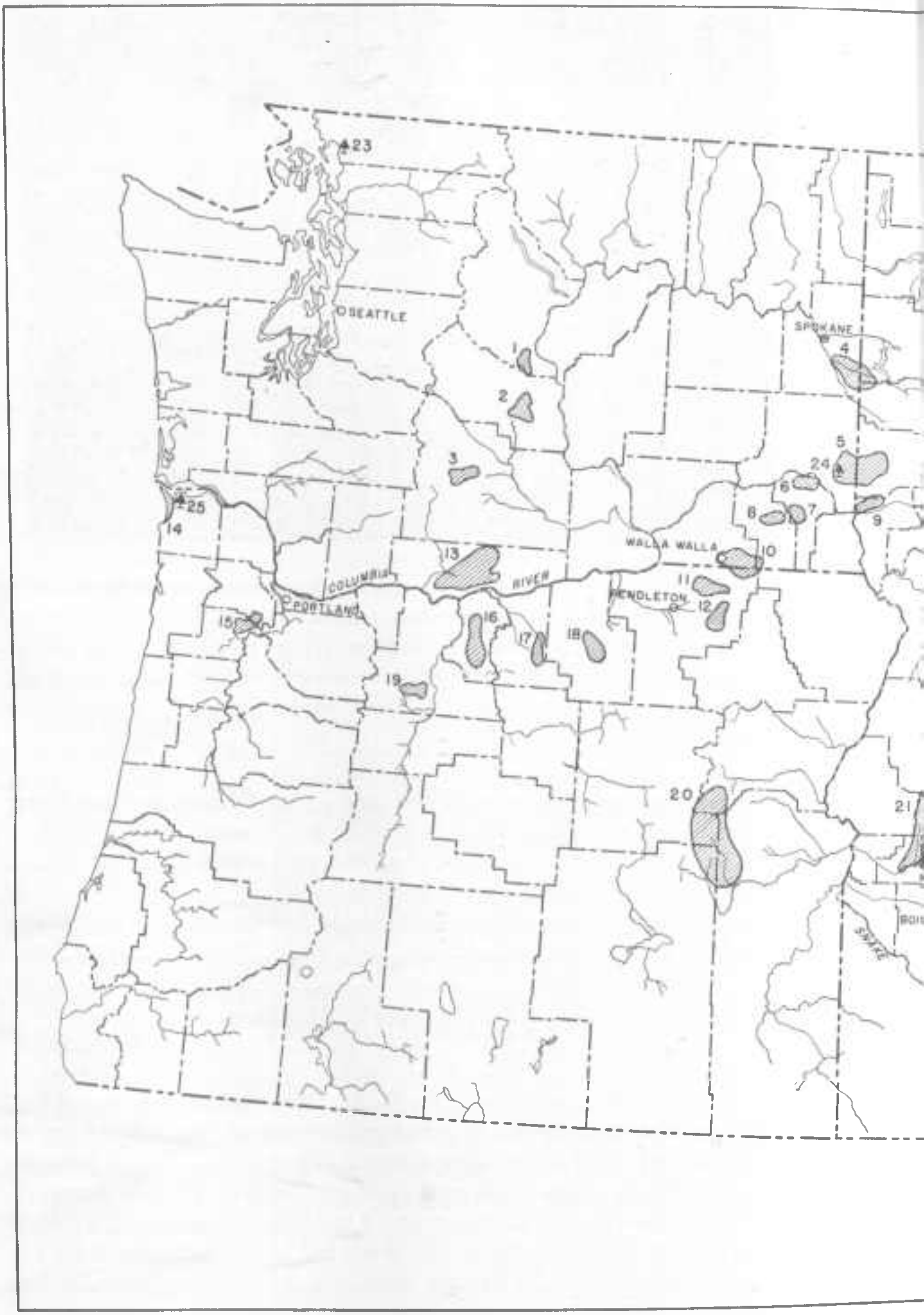
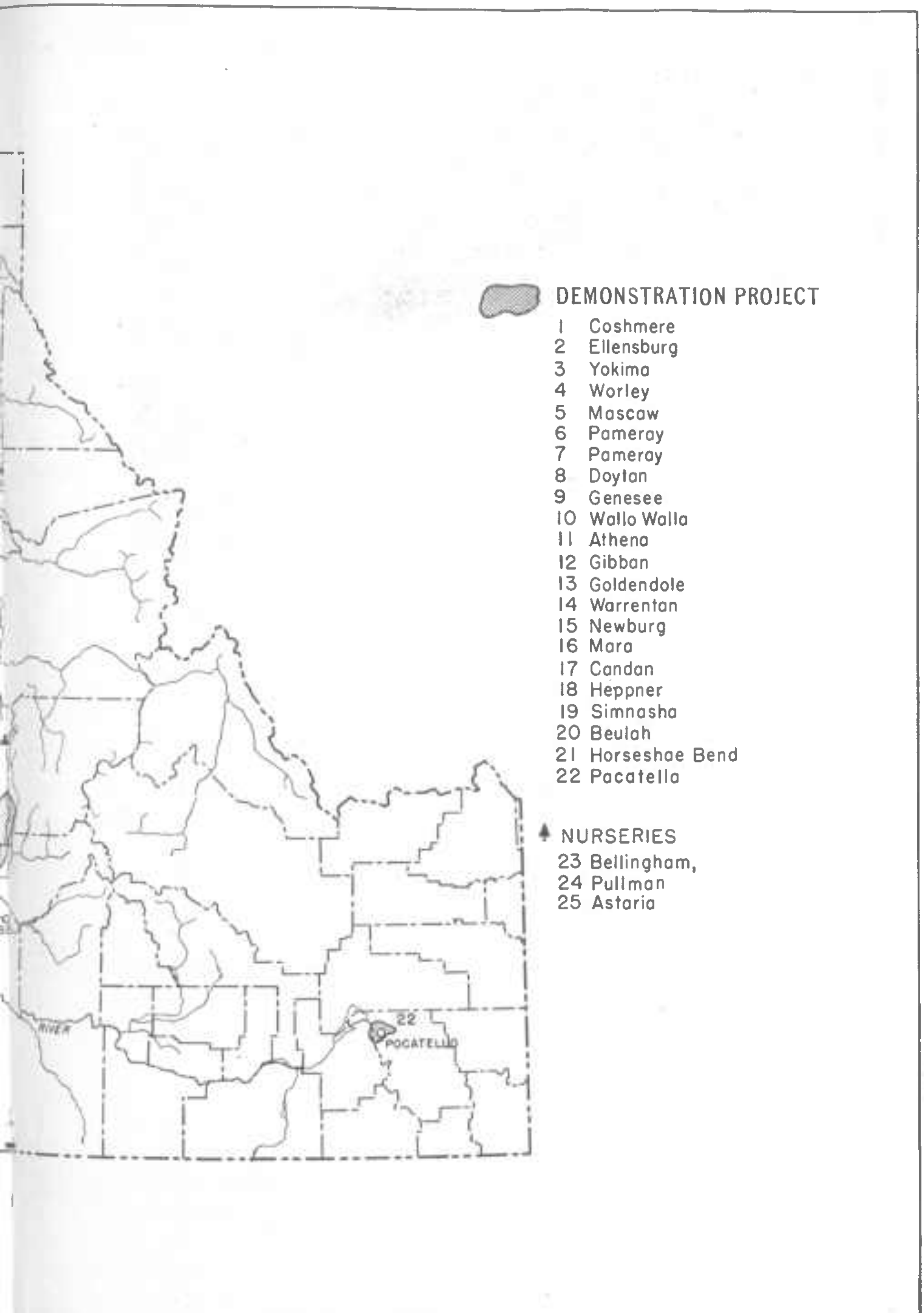


FIGURE 9.—*Various proven erosion-control practices are being demonstrated in proj*



jects located in the typical farming areas throughout the Northwest designated on the map.

FIGURE 18.—*To prevent soil from washing out of a newly filled and seeded gully, "whisker" dams are sometimes placed in series across the gully. The straw protrudes above the surface and checks washing until the new vegetation is sufficiently well established to afford protection.*

Gullies form wherever run-off water is excessively concentrated on a slope. They invade cultivated fields and overgrazed ranges. In some soils they cut rapidly; in others slowly. Gullies may erode a channel 5 feet deep and 10 feet wide in a single run-off period in soils formed from deposits of alluvial material. Some other soils strongly resist gully washing.

The differences in erodibility of soil types render uniform treatment of gullies impossible. In some localities the advance of gullies may be checked by building simple loose-rock or brush dams, or by staking straw in them. Behind these cheaply constructed dams soil collects. Seeded to a mixture of grasses and legumes, such gullies soon become stabilized. In some other localities stronger dams must be built to hold the soil while vegetation is gaining a foothold. Smaller gullies may be healed by being plowed in and seeded down. Some of the larger ones can be more quickly bank-sloped with a bulldozer—a huge blade pushed by a tractor. But whatever the type of dam employed or method used in sloping gully banks, the final control of gully washing rests with the vegetation that is grown in and along the sides of the gully. The roots and leaves and residues of growing plants themselves act as tiny dams which delav the flow of water and rob it of its cutting force.

So long as there is run-off from cultivated slopes, there is danger of gullying unless the more critical depressions in fields, where water concentrates, are withdrawn from cultivation and planted or seeded permanently to vegetation. When such natural drainage lines have become gullied, the practice on the conservation project areas is partly to fill them by plowing or by use of the bulldozer, and then firm and seed. The grading is done when the field is in stubble. Seedings employed are mixtures of grasses and legumes adapted to the locality. It is essential to produce a thick cover quickly in graded-in gullies, so that the freshly moved soil will not wash out during the first run-off period.

Sometimes seedings do not make strong growth the first season, and the fill-in is endangered. To prevent the soil from washing out, spreader boards, or straw wedges or "whisker" dams, are placed in series across the gully (fig. 18). Whisker dams consist of straw wedged in narrow trenches dug crosswise of the gully seeding. The straw protrudes above the surface and checks gully washing. This method has been used on the Athena, Oreg., project on some gullies lacking sufficient protection in the first season after treatment. During periods of heavy run-off none of the filled-in gullies cut deeply when protected by whisker dams. By the second year seedings are usually sufficiently strong to resist washing, and afford a source of valuable forage.

Supplemental forage is grown on narrow bottoms along some of the drainage areas in the lower Columbia grazing and farming lands. Formerly, the drainageways through these bottoms were shallow and U-shaped; but now, owing to gullying and deep cutting caused by increased run-off from overgrazed ranges, these bottoms are drained by deep gullies, and it is becoming increasingly difficult to grow alfalfa. By building a series of permanent rock dams across a gully the water table under the alluvial bottom may be raised, and forage may again be grown successfully (figs 19 and 20). Because proper range-management practices in these localities depend in large measure on having an adequate supply of supplemental feed for winter and early-spring feeding, it is highly important to preserve the productive capacity of these bottom lands. In the soil- and water-conservation areas of the Soil Conservation Service seedings of alfalfa and grass mixtures are displacing pure seedings of alfalfa on the bottoms. Mixed seedings are less difficult to establish and provide a better balanced livestock ration.

Three Farms

Up to this point, the various practices employed to control erosion have been described separately, as if each were an entity of itself. But as every farmer knows, the farm as a whole is the working unit; and for a soil-conservation program to be successful it must deal with the farm from this standpoint. A cropping program that checks losses of soil by blowing or washing and at the same time raises, or at least maintains, the level of income of the farmer, stands far greater chance of being accepted generally. That the cropping systems recom-

mended for controlling erosion may be judged from this point of view, three typical farms, one in each of the major wheat-growing areas of the Pacific Northwest, have been chosen as examples. Each is typical of farms in its area. The effect of reorganization upon each is described. The purpose is to show how the various measures of erosion control hitherto described are brought together, so to speak, into a coordinated program for the farm as a whole—to fit the various individual parcels or different kinds of land that usually go to make up a farm.

In the Palouse

Farm no. 1, located near Moscow, Idaho, comprises 796 acres. It is fairly typical of the farms in the Palouse area. Prior to the time the new cropping plan for the farm was developed with the Service, practically the whole farm was cropped in wheat-fallow sequence. Peas were grown on part of the summer fallow, followed by winter wheat. It was the custom to burn all crop residues. For several years one field of 17 acres had been in alfalfa. Sweetclover had been grown once in one field. Gullies 5 to 7 feet deep cut through some of the fields. The lighter colored clay subsoil on the badly eroded hilltops showed in sharp contrast to the surrounding darker colored topsoils.

The new plan called for seeding these hilltops to a mixture of alfalfa, bromegrass, and crested wheatgrass. The gullies were worked in by tractor plow and grader. Spreader boards and a few dams were inserted to protect the fill-in in the larger gullies. The filled gullies were seeded to a mixture of alsike clover, redtop, bromegrass, and meadow fescue. Sloped and seeded in this way, gullies became permanent waterways that could be crossed by machinery, which for several years had not been possible. All natural grass areas were left undisturbed.

The plan also called for seeding 321 acres of sweetclover to be plowed under as a green-manure crop. Part of the sweetclover acreage was seeded with peas, and part was sown alone in the normal summer-fallow year. All residues from the wheat and peas will be worked into the soil, according to agreement, and all tillage operations will follow the contour.

Part of the farm is fairly level land, and erosion there was not severe. No immediate changes are planned for the cropping system on this part of the farm, although the owner plans eventually to bring this land also into a sweetclover rotation.

A small area of waste land was planted to black locust, and a windbreak planting was set out with a view to protecting the farm buildings from drifting snow and cold winds.

A piece of old alfalfa was badly infested with cheat, and this was plowed up, to be cropped for 3 or 4 years before being reseeded to a mixture of alfalfa and grass. The effect of the reorganization of the farm appears in table 2.

TABLE 2.—*Details of reorganization of a typical Palouse farm for soil- and water-conservation purposes*

Land use	Before agreement	After agreement	Notes on changes in farm practices
	Acres	*Acres*	
Wheat-fallow sequence	758.5	379.5	Residues from crops are mixed with the surface soil; none will be burned. All tillage will follow the contour.
Sweetclover rotation	0	321.0	Sweetclover to be plowed under for green manure in preparation for wheat the following year.
Native grass	15.8	15.8	
Permanent seedings	17.0	67.5	17 acres of old alfalfa were broken up and put into wheat-fallow sequence; 67.5 acres of eroded hilltops and steep slopes were seeded to alfalfa-grass mixtures.
Gully seedings	0	6.0	
Tree plantings	0	1.8	
Waste land	1.3	0	
Farmstead and roads	4.2	4.2	

In the Blue Mountain Foothills

Farm no. 2, comprising 414 acres, is located on Mustard Hollow Creek, near Dayton, Wash. It is typical of the farms in the foothill country of the Blue Mountains. Its soil is a prairie-type silt loam that erodes easily. Gullies had cut one field of 128 acres into five parts; some of the gullies were 20 feet deep and in places almost as wide. This field at one time was worked as one unit. The land is rolling, and the hilltops and slopes have lost much of their topsoil; the subsoil shows through on nearly all the hills.

Before the cooperative agreement with the Service was signed, the entire farm except for the deep gullies was seeded in wheat-fallow sequence. On most of the farm the summer-fallow and winter-wheat system was followed, but on some of the better land the sequence was winter wheat, spring wheat, summer fallow. All stubble had been burned in the past. Grain was used for hay, and there were no permanent forage seedings.

Under the new cropping program 42 acres on the hilltops and on the more severely eroded slopes were seeded to alfalfa and grass. These are permanent seedings. Forty-six log dams, 1 masonry dam, and 123 straw, stake, and wire dams were constructed in gullies. As soon as gullies fill with silt behind these dams, their banks will be sloped and seeded. Once a vegetative cover is established they will serve as permanent vegetated waterways for taking care of water during the occasional thundershower or severe spring thaw. In all, 60.5 acres are seeded to permanent cover on the 404-acre farm.

The rest of the farm will be seeded to sweetclover at least once during the 5-year period covered by the cooperative working agreement. The sweetclover will be grazed and then turned under for green manure. Meanwhile, all tillage will be on the contour, and all residues from crops will be mixed with the surface

soil. Table 3 shows the effect of reorganization of the cropping plan on this farm.

TABLE 3.—*Details of reorganization of a typical farm in the Blue Mountain section for soil- and water-conservation purposes*

Land use	Before agreement	After agreement	Notes on changes in farm practices
	Acres	*Acres*	
Wheat–summer–fallow sequence.	395	0	Residues from crops are mixed with the surface soil; none will be burned. All tillage will follow the contour.
Sweetclover rotation	0	334.5	Sweetclover plowed under for green manure in preparation for wheat the following year.
Permanent seedings for hay	0	42	Alfalfa-grass seedings located on hilltops and steep eroded slopes supply forage.
Gully seedings	0	18.5	To remain as vegetated waterways.
Farmstead and roads	9	9	

On the Columbia Plateau

Farm no. 3 is a 1,000-acre farm near Condon. It is situated on the Columbia Plateau in north-central Oregon, where the rainfall averages not more than 10 inches a year. The soils are fine sandy loams and loams. Owing to the deficiency in rainfall, wheat cannot be grown successfully without summer fallowing in alternate years to store moisture in the soil.

Before the owner worked out a new cropping plan with the representative of the Service, all of the agricultural land on the farm was in wheat and summer fallow. The range was badly overgrazed; one or two sandy spots on a canyon slope had begun to blow. The agricultural soil on the plateau is thin, and continued cropping and pasturing of the stubble had induced considerable loss of valuable topsoil by sheet washing.

The new cropping plan provides, first, for supplementing the grazing land by seeding part of the agricultural acreage to crested wheatgrass. These seedings are on areas that adjoin the canyons and that, in past performance, have proved unprofitable for wheat growing, crop failures being more frequent than crop successes mainly because the soil is shallow.

The owner agreed to employ tillage practices and tillage implements which concentrate all crop residues in and near the surface of the soil. Since the soils are relatively well supplied with nitrogen, stubble can be utilized in this way without danger of depressing yields. The owner also agreed to till his land on the contour according to the general principles laid down in the section of this bulletin dealing with soil-saving tillage practices for dry-land areas.

In the places that had begun to blow, trees, principally black locust, Russian-olive, and caragana, are planted in strategic locations in contour furrows. The

contour furrows aid in securing greater penetration of soil moisture to start the trees, which are species fairly resistant to drought.

Dams have been constructed to store water for livestock and for other purposes, such as flood-water spreading for production of forage crops. Some additional fencing of grazing lands permits the practice of deferred and rotational grazing.

Table 4 shows the effect of the reorganization on this farm.

TABLE 4.—*Details of reorganization of a typical farm in the Columbia dry-land area, for soil- and water-conservation purposes*

Land use	Before agreement	After agreement	Notes on changes in farm practices
	Acres	*Acres*	
Native grazing land	300.4	296.4	To practice deferred and rotational grazing on range.
Wheat—summer-fallow sequence.	688.5	649.5	Crop residues to be conserved on all wheat-land and incorporated with topsoil.
Gullies	3.6	2.5	1.1 acres gullied land planted to trees; dams constructed on the rest.
Permanent grass seedings	0	39.0	Crested wheatgrass seedings to supply forage for relief of range.
Trees	0	5.1	Trees planted to prevent blow areas from spreading.
Farmstead and roads	7.5	7.5	

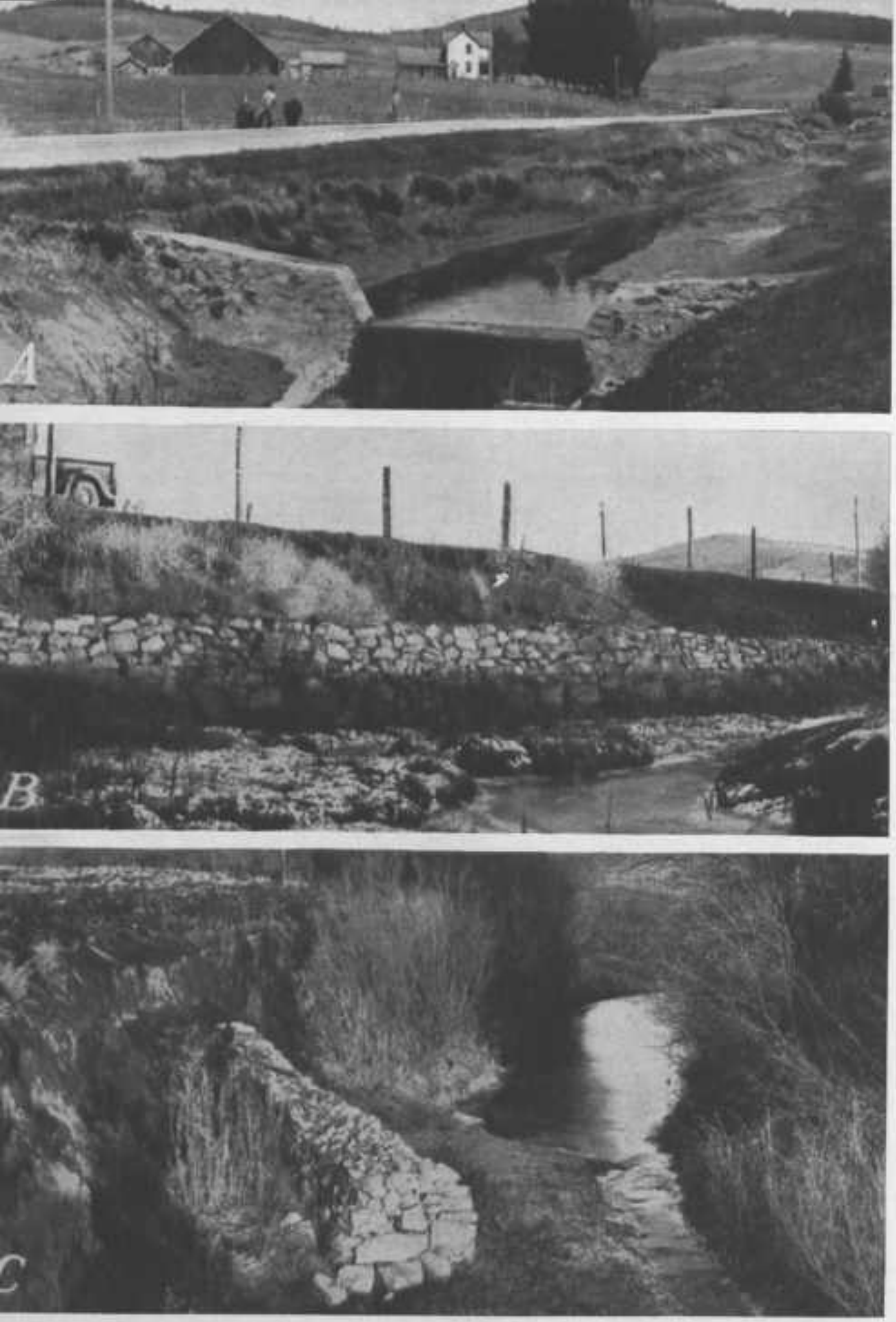


FIGURE 19.—*Some permanent structures used in soil- and water-conservation programs in the Pacific Northwest:* A, *Masonry dam for stabilizing a gully along a highway;* B, *rock-wire revetment to protect stream bank from sloughing and destroying roadbed; and* C, *a jetty, also for stream bank and bottom land field protection.*

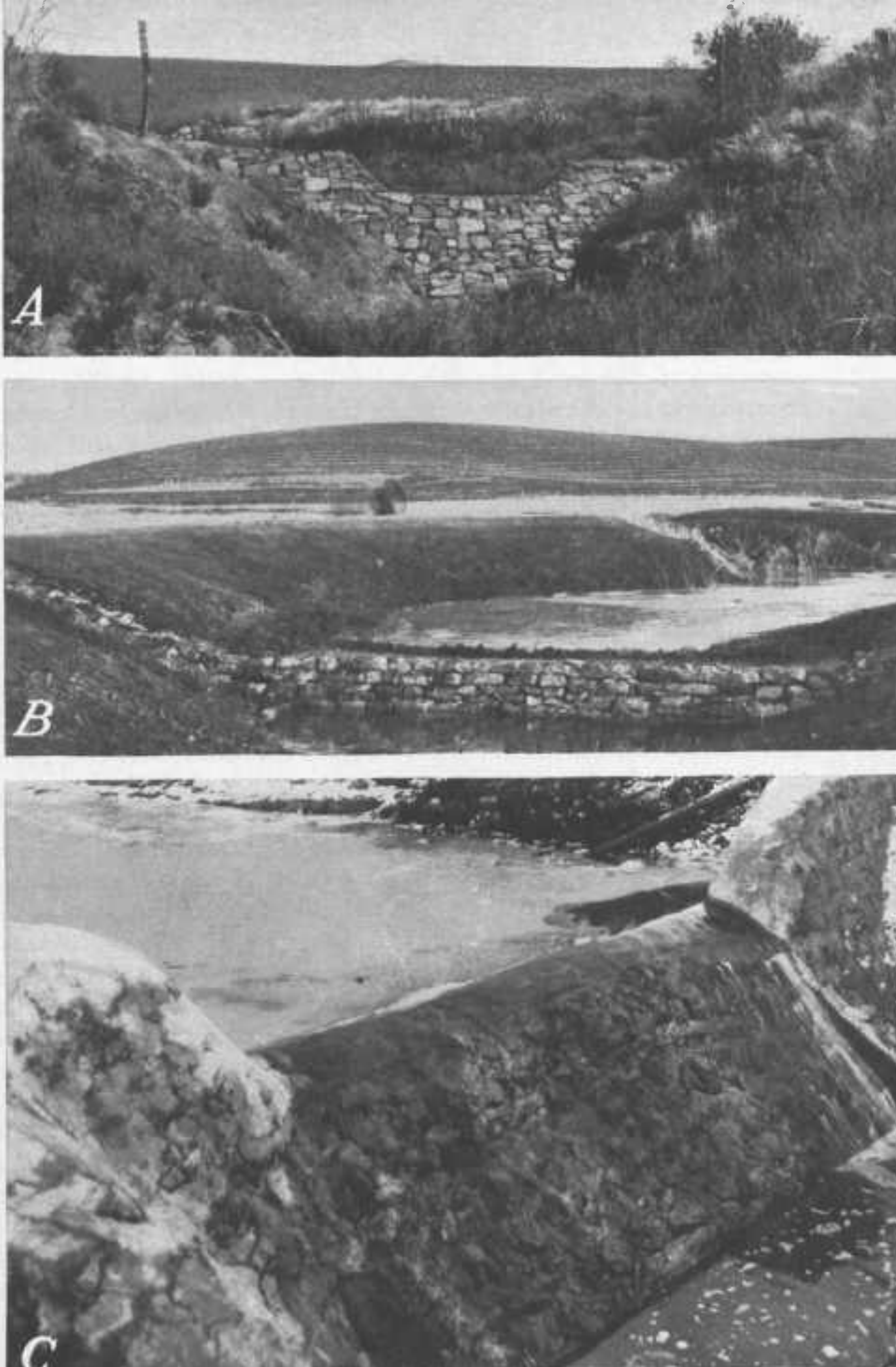


FIGURE 20.—*More soil- and water-conservation structures:* A, *Permanent rock-wire dam in revegetated gully;* B, *rock-wire dam with crushed rock rubble for main channel stabilization in stream; and* C, *flat masonry dam in stream to raise water table.*

In Defense of the Range

IN THE EARLY days of the Northwest no one seems to have expressed concern about misuse of the range. The pioneers at first believed there was plenty of grass for all, and later, when keen competition for the range led to wars between stockmen, the exploiters of the range were too busy espousing their rights to think about preserving the grass. Most of the range was public domain, and no one, indeed, felt any responsibility for it. There was the range, free, to be used, they felt, and the early comers used it according to their individualistic principles of "might makes right" and "first come first served." As a result, the range lands of the Northwest were severely grazed even before the development of farming.

But the era of real damage to the range of the Pacific Northwest began with the development of farming. Those parts of the Northwest which furnished the best pasturage were the first to be plowed for wheat. Here the bunchgrass grew most luxuriantly in a more nearly humid climate and in deeper, richer soils The plow-up began in the seventies. From then on wheatfields closed in on the stockmen, who were pushed into drier, more rugged and broken, sometimes almost inaccessible areas not suited to cultivation.

While the range was growing smaller and less desirable, the numbers of cattle and sheep increased, not only in the Northwest, but all over the western range, and supplies overstepped demand, with the usual result. Prices slipped, then slammed down. Choice beef on the Chicago market in 1885 brought $2.50 a hundredweight. It was hardly worth while to ship $2 beef, and stockmen held their cattle on the range to increase. More stock was on the range than it could support year in and year out. The era of overgrazing was on in full swing. The range has never been given a chance to recover from the beating of those early days.

Overstocking and improper seasonal use are the primary causes of erosion on the range. Constant overgrazing thins out the bunchgrass species, which provide the finest native pasturage in the Northwest. Grazed each spring before enough plant food is produced for continuous growth, the perennial bunchgrasses gradually give way before the competition of the less valuable, quick-growing, shallow-rooted annual grasses and weeds. Plants of excellent soil-binding qualities, in a word, are succeeded by plants of inferior soil-binding qualities (fig. 21).

Some experiments carried on by the Forest Service reveal the rapidity with which soil is washed away when the plant cover becomes less effective in resist-

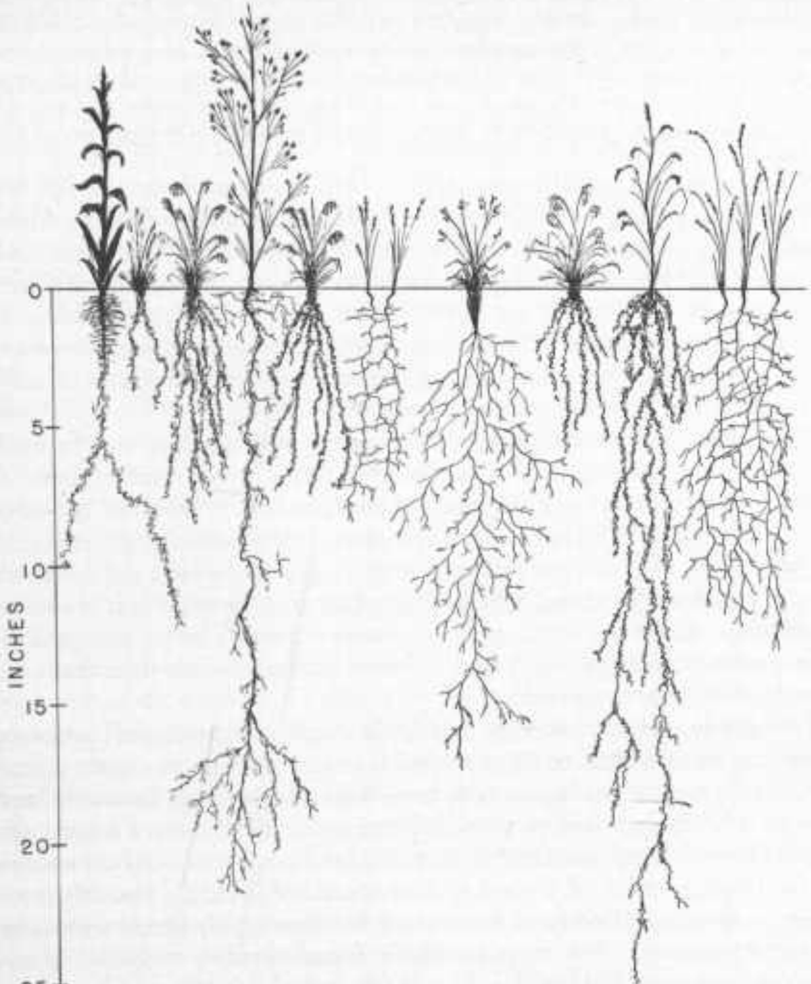


FIGURE 21.—*Plants of excellent soil-binding qualities give way before plants of inferior soil-binding qualities, on overgrazed ranges. Compare the root systems of these annual weeds and grasses with the root systems of bunchgrasses, shown in figure 3. (Drawing by Forest Service.)*

ing erosion. In studies on the Boise River watershed, in Idaho, the Forest Service employed a portable apparatus to simulate natural rainfall and measured the run-off of water and soil losses under different types of cover. The bunchgrass cover yielded a negligible amount of run-off and silt. Further, as Bailey and Connaughton report in The Western Range (74th Cong., 1st sess., S. Doc., 199, p. 7):

The downy chess [cheat] and needlegrass-lupine types, which have succeeded the bunchgrasses on overgrazed ranges at the lower and higher elevations, respectively, are distinctly less effective

watershed covers. The manner in which these two types contribute to rapid run-off and erosion is shown by the fact that, on the average, 25.5 percent of the precipitation on the downy-chess cover and 47.6 percent of the precipitation on the needlegrass-lupine cover were unabsorbed. Further, as this water ran off it carried the equivalent of 2,017 and 4,783 pounds of soil per acre from the respective types. The annual weed type afforded far less protection than any of the others, permitting a 60.8 percent run-off which transported an equivalent of 15,280 pounds of soil per acre.

Even before the topsoil erodes away, harmful changes are wrought in range soils by overgrazing. The change from a vigorously growing, heavy fibrous-rooted cover of vegetation to a sparse, semitaprooted cover is accompanied by depletion in the content of organic material in the soil. As its organic material is used up by decay and is not replenished, the soil becomes less cohesive and less able to absorb water. The granules of soil, disintegrating, separate into the smaller particles that go to form such aggregates, under the continuous trampling that unfits the soil to resist blowing as well as washing.

The organic content of the topsoil of the range, once it is lost, may be replenished only through long years of careful management. The rancher, unlike the farmer, may not resort to a few crops of green manure to replenish the supply of organic material in his soil within a few years. He is limited to preserving and protecting the type of cover nature chooses to give to the land and must await nature's readiness to proceed from one type of cover to the cover next in a natural succession. Each stage in the plant succession requires a better soil condition. The preservation of the top 2 or 3 inches of soil is essential, therefore, to the preservation of the range itself.

Fortunately, most of the range land in the Pacific Northwest still has enough topsoil to be able again to move toward a climax cover under careful management; soils men and ecologists who have surveyed the range estimate that 82 percent of the range will progress, if properly managed, toward a bunchgrass type of cover. They base their opinion on a large number of observed examples of the beneficial effect on the soil of close control of grazing. There is, for example, a range near Condon, Oreg., which has been lightly grazed since it was fenced 8 years ago. The range across the fence is eroding seriously, whereas there is evidence of little soil loss from the fenced range. The perennial grasses on the unfenced range are few and low in vigor; the heavier stands are composed chiefly of low-value plants. On the fenced range there are few invaders, and the bunchgrass is vigorous and abundant.

In southeastern Oregon there are several areas of the public domain which have been moderately grazed. They support a fair stand of climax bunchgrass. While some soil losses are occurring, the bunchgrass cover contrasts sharply with the almost bare range surrounding it. Were this range grazed a little less heavily, soil losses would become unimportant within a few years.

Management practices that preserve the soil as well as the grass cover are fairly well known. Often they have not been put into use because economic forces outside the control of the rancher interfered. In many areas the complex owner-

ship pattern renders a united action exceedingly difficult. Also, the worth of erosion-control practices has not everywhere been clearly demonstrated. Although some stockmen long have known and recognized the change in composition and the falling off in feeding value of the forage cover on the range, few recognize that the changes in cover permit the soil itself to wash away from under their feet.

In half a dozen range areas in the Pacific Northwest, the Soil Conservation Service has selected whole watersheds on which to demonstrate and thereby encourage the widespread use of soil- and water-conserving practices on range lands. The corrective measures introduced in these areas are of such a practical nature that the individual range operator may duplicate them on his own holdings. Such conservation projects, as indicated in figure 9 (pp. 28 and 59), are located at Emmett and Genessee, Idaho; Goldendale, Pomeroy, and Dayton, Wash.; and Beulah, Gibbon, Heppner, Moro, Condon, and Simnasho, Oreg. Work was begun on watersheds near these points during 1935. The discussion of range-management practices which follows describes the corrective measures ranchers, in cooperation with the Service, are effecting in these conservation projects.

Overstocking: A Primary Evil

The success of any system of range management depends first of all upon careful adjustment of the number of livestock to the grazing capacity of the forage on the range. Unfortunately, because of financial pressure, this is the most difficult phase of range management. A range may support a certain number of stock 1 year without being injured, and in another year, perhaps because of drought, suffer serious damage while being grazed by the same number of stock. Also, the the number of head a range will support with profit depends largely on the system of management that is followed.

Stockmen in general have failed to make adjustments in grazing practices quickly enough to save the grass. This is due, in part, to overoptimism in regard to the length of time required for range grasses to recover following a period of abuse. An abused range recovers very slowly (fig. 22). And too often ranchers hard-pressed for money to meet mortgage payments, believe that they can do so only by carrying the greatest number of livestock a range seemingly can support. If the range is to be conserved, stocking in the future must be based on careful analysis and study of the requirements of the forage plants themselves. For soil and water conservation the number of stock must be adjusted to the grazing capacity of the range based on information obtained in years of average or low forage production rather than on years of favorable or above-average production. This is a fundamental principle of good range management too often overlooked. In all years the forage should be utilized only to such an extent that not less than about 20 or 30 percent of the perennial forage plants remains on the ground to protect the soil during periods of surface

FIGURE 22.—*Serious topsoil losses have occurred on this range once regarded as impossible to damage by grazing. Fifty years ago 10 acres supported one cow; now 100 to 150 acres are required. Concentration of water in the bottoms, permitted by the sparse vegetation, sluiced out the main drainageway to a depth of 20 to 25 feet and a width of 250 feet.*

run-off and high winds in the winter and spring. This does not necessarily imply that for a period of years profits will be less to the rancher. There is ample evidence that overstocking yields less immediate profit, as well as less profit in the long run, than does careful stocking according to the needs of the grass. Under conditions of limited grass, in a word, the stockman must be a grower of plants as well as an animal husbandman. His success depends now on how much feed he produces and how economically it is produced.

Some measure of control of overstocking may be effected, by Government assistance, on ranges adjacent to public-domain grazing land, if the rancher makes use of the public range. The Forest Service for years has limited the number of head of livestock a permittee is allowed to graze in the national forests to the sustained grazing capacity of his range. More recently the Division of Grazing of the United States Department of the Interior, in the grazing districts authorized by the Taylor Act, began as a basis for granting permits to limit the grazing privileges of permittees to the public domain according to the amount of feed the individual rancher has available for the seasons his stock are not on public range.

Prospecting for Water

Much of the range of the Northwest is inadequately supplied with watering places. There are fewer springs than there used to be, and fewer wells. Many

springs which at one time flowed through all or most of the summer season either have ceased to flow or flow with a greatly reduced head. Overgrazing, with resultant impairment of the cover and accelerated erosion, is responsible. Water no longer percolates into soils of range watersheds as readily as it used to. Since the plant cover has been made sparse by overgrazing more water runs over the surface, and less works its way through the soil to reappear as springs or seeps. Similarly, in many areas stripped by erosion of all or a major part of the humus-charged topsoil, water speeds away to the valleys—over the surface, not by way of the substrata of the soil.

Tremendous gullies have drained large areas and lowered the water table in valley meadows (fig. 23). The bottoms of many wells consequently stand high

FIGURE 23.—*After the bunchgrasses succumb, the run-off of water over the surface of the soil becomes rapid and cuts deep gullies. Gullies drain alluvial bottoms and lower the water table.*

above the present level of ground water. Some of these newly established gullies are 60 to 100 feet deep, 200 to 300 feet wide, and 10 or 20 miles long. They form in the deep deposits of alluvial soil which through centuries have accumulated in the valleys of the range country, washed down from the hillsides little by little. Such a gully near Hay, Wash., cuts through a ranchstead, now abandoned, that once watered 300 head of cattle. One may stand on the floor of this huge gully and see buildings overhanging the gully bank on one side, and 30 feet above one's head on the opposite bank, a cross section of a well etched in the gully wall.

The failure of many of the watering places on the range tended further to concentrate livestock and to cause a far greater amount of travel to and from water. Naturally cattle prefer to graze in the better watered areas. They go to these

first, when turned on the range, and stay too long, neglecting the outlying, less accessible parts of the range which, although they may produce good forage, lie too far from water. Cattle congregating at watering places destroy all of the vegetation sometimes for several hundred yards around, and severely deplete the range cover to a distance of a mile, while soil and vegetation suffer from the travel of stock from the water holes to grass farther removed. Experience has shown that watering places on cattle ranges should be less than 3 miles apart, so that stock do not have to go more than 1½ miles for water; on rougher range, water places should be spaced even closer. Increasing the number of properly located watering places on a sheep range will curb severe soil losses caused by damage to the range from excessive trailing.

FIGURE 24.—*The development of new watering places helps to distribute stock more satisfactorily over the range. Even a very small spring will water a surprisingly large number of stock if the water is all caught and piped to a watertight trough.*

The development of new sources of water supply properly spaced is an important first step in the range-conservation program in demonstration projects (fig. 24). Where possible, this is done by developing springs or seeps. Sometimes wells are drilled, or dams are constructed to store spring run-off water. These structures on most of the western range, however, are usually more costly than small spring developments. Except in the high desert section of central and southeastern Oregon, the number of potential watering places on the range of the Northwest, were they developed, appears ample to distribute grazing satisfactorily over the whole range.

On the range-conservation projects of the Soil Conservation Service springs, or seeps, which are sometimes not more than puddles, are excavated; and in the hole, a concrete catchment basin is built, usually about 4 by 4 feet. The concrete basin is covered, and the water is piped to a trough, made of plank, concrete, or a log, 15 to 40 yards away. The area around the spring is fenced to a distance of 10 to 30 yards to prevent injury from stock.

Even a very small spring will furnish water for a surprisingly large number of stock if the water is all caught and piped to a watertight trough.

Range Management

Early spring is the critical period for the range. Until bunchgrasses attain a height of 6 or 8 inches they are unable to withstand grazing without serious injury. Food for the plant is manufactured in its leaves. If these are removed either by cultivation or premature grazing, before they have fulfilled their function, the result is starvation for the plant. It is the common practice in most of the Northwest range country to turn out cattle and sheep as soon as the young shoots show green. This kind of treatment will kill bunchgrass; it is very like the method used to kill persistent weeds in cultivated fields.

After the proper stage of growth is reached conservative grazing does little damage to the plant. By this time the soil is drier, and trampling by livestock does less injury. A period of delay, in addition to permitting more leaf growth, encourages root growth.

Stockmen who make the best use of the range think of conserving the soil as well as of the grazing capacity of the forage crop. The stockman whose management practices are not governed by this dual consideration uses the range in a way he considers to his greatest immediate advantage. He turns on his stock as soon as the range shows green in the spring and through the season strives to utilize every leaf for forage. If some growth remains after the stock are taken off he considers it a waste of forage. But the stockman who governs his practices to improve the forage cover through the years manages to leave a proper amount of the growth to supply the required storage of nutrients in the roots to sustain vigor, and to provide a protective cover for the soil during the period of winter precipitation.

About a fourth of the growth of the more important forage plants should be permitted to stand, although under conditions of severely depleted cover, on steep slopes, or shallow soils, a much greater proportion of such growth is required to hold the soil. The erosion-retarding bunchgrasses and other species of plants found on a well-managed range and the organic residue from these plants check the run-off over the surface and increase infiltration of water into the soil. This increase in the store of soil moisture stimulates growth. The better range plants draw upon it and increase in vigor and density.

Although the immediate effect of proper management is to increase the quantity of forage produced, often the number of forage plants must multiply several times before there is a sufficient density of new plants of the interbunch species to retard erosion. Therefore, although the grazing capacity of the range is increased, no increase in stocking should follow until the vegetative cover is sufficiently dense to hold soil losses to a normal rate.

Bunchgrasses normally reproduce from seed, except for the increase in number of plants within the individual bunch. This is in contrast to sod-forming grasses which, especially when subjected to excessive grazing, reproduce from underground rootstalks. Therefore, to perpetuate a stand of bunchgrass, it is necessary to provide an opportunity for the bunchgrasses to produce a seed

FIGURE 25.—*If bunchgrasses are to compete with low-value plants, they must be permitted to produce viable seed at least once in 4 or 5 years. There is a fair stand of bunchgrass on the right side of the fence where grazing is controlled. On the left, the soil is almost bare of vegetation owing to severe overgrazing.*

crop. Close grazing year after year, and especially very early in the spring, prevents viable seed from maturing; or, if grazed heavily the seed stalks are eaten before seed is formed. This in a large measure accounts for the successful invasion of the former bunchgrass ranges by such low-value annual grasses as cheat. Stock generally prefer the bunchgrass species to annuals, many of which are unpalatable except for very short periods in the spring. They naturally neglect these and feed on the superior bunchgrasses. The annuals, although heavily grazed, on being released from grazing, produce viable seed abundantly.

If the bunchgrasses are to compete with low-value perennial and annual grasses and weeds, the system of range management must be adjusted to permit production of viable seed at least once in 4 or 5 years (fig. 25). Until this is done the bunchgrass species will continue to disappear from large areas of the open range of the Northwest. How far this trend has proceeded is shown by comparison of ungrazed bunchgrass cover with an average range cover of today. In virgin stands fully three-quarters of the plants on the ranges of the Pacific Northwest were bunchgrass species. On overgrazed ranges this proportion has dropped to an unimportant percentage and in large areas the bunchgrasses have practically disappeared. On virgin range there is seldom more than a trace of palatable annual plants. On most ranges today more than half of the cover is of annual-grass type.

The system of management that offers the bunchgrass species best opportunity to recover and stabilize the soil, aside from sharply decreased stocking or closure to grazing, is deferred and rotation grazing. Under this system of management the bunchgrasses have, at least in an occasional year, an equal opportunity with the annual grasses to produce a seed crop.

One plan is to divide the range into several subunits, say three to five, based on the period from seed maturity to the end of the grazing season. Each year grazing is deferred on one of the units until after seed is matured and shed. The stock then are turned on to graze and to scatter and trample the seed into the soil so that seed germination is more certain. In the second year another unit of the range is protected until seed is scattered, and the cycle of rotation is continued until each unit of the range has enjoyed a protected season. The unit on which grazing is deferred to the last in 1 year, is grazed second from last in the succeeding year. Young seedling plants thus are given added opportunity to grow and become established. When this system of rehabilitation is applied to an eroded range, the more desirable species of bunchgrass revegetate the range very slowly. There are many species of perennials and annuals which must precede the final dominance of the area by the bunchgrasses. Later, as the process of rehabilitation progresses, the clumps of bunchgrass become more numerous. If the range is conservatively grazed for some years thereafter, the bunchgrasses may be expected to make steady headway, finally approaching a condition of desired permanence and providing adequate soil protection.

After seed is matured most plants will withstand removal of as much of the forage as it is ever desirable to remove from a range; but about 20 or 30 percent of the forage should be permitted to stand to aid in the accumulation of snow, which results in an increased amount of water for penetration into the soil. This remaining forage also protects the soil during the periods of run-off in the winter and spring.

A system of deferred and rotation grazing operates very successfully on sheep ranges, for sheep may be held under close control. On cattle ranges which do not happen to separate into subunits by natural barriers, the system cannot operate

up to its fullest promise except when the range is fenced or the cattle are closely herded. However, a careful salting program correlated with a program for developing more watering places helps to spread stock to those parts of the range that they must graze to effect success for a rotation system of management. Rotational grazing is especially adapted to the use of stockmen who market directly from the range in the fall. The system provides a supply of good forage for use immediately before the stock are marketed.

Salt: A Cheap Cowboy

Cattlemen frequently make use of the natural craving of animals for salt to aid in moving stock from one part of the range to another according to the readiness of the range for grazing.

Forage plants on most western ranges do not develop uniformly with the season. Some parts of the range are ready for grazing before others. Each rise of 1,000 feet in altitude, for example, accounts, as a rule, for a delay of about 7 to 14 days in the period in the spring that grass begins to grow. Some slopes exposed less directly to the sun's rays do not green up until the grass is well along on slopes that are otherwise comparable.

The permanent watering places on the range are often located in the valley meadows. Cattle tend to congregate there. One means of enticing cattle from a valley meadow before they have grazed so long as to damage the soil is to place salt in or near localities which it is desirable to have grazed. Cattle tend naturally to graze from water to salt and from salt to water, and thus, if they are properly salted, their grazing will be more nearly distributed over the entire area rather than restricted to within the vicinity of water. The old practice of salting at the watering places often in areas of best forage hurried the deterioration of many valuable parts of the range and was wasteful of good forage on areas away from water.

A measure most helpful in connection with the work on the soil- and water-conservation areas is salt placement according to plan. The purposes of the plan, roughly, are to hold the cattle from a range which is not yet ready for grazing and to attract cattle away from the areas that are being grazed too closely, thus aiding in securing proper distribution of the stock.

Salt troughs on the larger ranges are arranged in several series, as an aid in securing distribution of grazing. Troughs on the earliest range are filled first; troughs on the later range next; and troughs on the third series at a still later date. Thus, as the grass develops in the spring in the higher altitudes and on delayed exposures, cattle may be led there to make best use of the new forage. For the system to be effective, the unused salt in the troughs in the grazed area must be removed. Otherwise some cattle will remain near the salting troughs filled first and overgraze the early range. As the season advances the order of filling may be reversed to aid in bringing the cattle down from the higher range to the lower range.

On many ranges, particularly on those that have been overgrazed in the past, there are large areas of annual plants which grow vigorously in the spring. Some of these annuals furnish good forage for a short period. But if they are not grazed when succulent and green, their forage value is lost. Annuals mature quickly and soon become dry, unpalatable, and the seed parts often injure the mouth, nostrils, eyes, and digestive tract of the grazing animal. These areas should be salted while the crop of annuals is in best forage condition.

Structural Aids

A number of structural aids, of which a few at first thought appear unrelated to erosion control, are employed in soil- and water-conservation demonstration districts on the range. Drift fences are a familiar feature of the range, and bull pastures and corrals; but contour furrows and gully dams are innovations. Only a few words are required to point out the significance of each of these several types of structures to a well-rounded erosion-control program.

Fences

It has been pointed out that proper distribution of the stock over the grazing area is an exceedingly important phase of range management, for profitable use of the forage as well as for preservation of the grass and resultant conservation

FIGURE 26.—*Drift fences hold cattle from range that is not yet ready for grazing. This buck-pole drift fence separates spring from summer range and prevents cattle from moving on to the higher range until the grass is ready, when the bars are let down.*

of the soil. The ideal arrangement is to put all land under fence, but on the far-flung low-capacity ranges of the Northwest fencing often involves a large capital investment. Within the conservation project areas ranchers are coming to use drift fences, to hold cattle back from moving on to unready range. Cattle, for instance, have a marked tendency to follow the snow line in the spring, advancing as the snow recedes and nipping the grass before it becomes fairly started in the spring. Drift fences (fig. 26) hold the cattle back and permit distribution of cattle over the range according to forage readiness.

Corrals

Whenever stock is removed from the range the result, broadly speaking, is some measure of erosion control. If this can be done in certain seasons only by feeding in corrals, an investment in this type of structure will repay the rancher by effecting better distribution of cattle and consequently eliminating a frequent cause of severe local overgrazing. On one conservation project, stock were removed from an overgrazed range in the dead of winter in 1935–36 for the first time in the history of that range, as a consequence of building a corral. On the larger ranches the use of several corrals rather than one reduces damage from excessive trailing and overconcentration of cattle within the immediate vicinity of the corral; and on many ranges sale of fat stock, elimination of breeding stock, and other management practices which result in relief to the range cannot be followed without corrals.

Contour Furrows

On some of the slopes in all range-conservation demonstration projects the Soil Conservation Service is building contour furrows to show the practical worth of this type of erosion-control measure. The furrows are run in many instances on overgrazed areas which have begun to erode severely. The idea is to throw a horizontal or contour furrow along the slope to catch the water as it runs down the hill. Water, caught in the basin of the furrow, percolates into the soil and stimulates the growth of grass seeded on the furrow. The furrows are built exactly on the contour of the slope, on dead level, by following lines laid out by the use of surveyors' instruments. They usually are spaced about 25 feet apart, the exact distance depending on the sparseness of cover and the degree of slope. It has been observed that areas between furrows regrass quickly if they are protected from grazing while the young grasses are getting started and that low furrow ridges revegetate more quickly than high ridges.

Bull Pastures

If bulls run with the cows the year round, calves are dropped the year round. The ranchman thus faces a problem each winter. Shall he turn his cattle on winter range, where there is some feed, or shall he hold them close to the ranch

house on spring-fall range where there is very little feed but where he can take care of his cows when they calve? If he turns them on winter range he undoubtedly will lose some calves and cows during stormy weather. If he holds them on the home range his supply of feed likely will be insufficient to carry his stock safely through the winter.

On ranges which provide forage in all seasons, in demonstration districts, this problem is solved by fencing off certain areas over the range for bull pastures and segregating the bulls from the cows except from June through September. Calves then are dropped in February through May, when the weather is more moderate than in the dead of winter.

The use of bull pastures permits proper seasonal distribution of cattle over the entire range unit; it relieves the spring-fall range from overgrazing, which reduces soil losses and conserves the cover of vegetation.

Dune Sands Bound by Grass

HIGH TIDES SWEEP huge quantities of sand upon the beaches along the coast of Washington and Oregon. Picked up by winds, which blow prevailingly in an inland direction, this sand is piled into dunes, which roll overland. In the paths of the surging dunes are valuable public and private properties (fig. 27)—roads, parks, recreational resorts, summer homes and other buildings, farm lands, Government military reservations.

FIGURE 27.—*In the paths of the surging dune sands are valuable properties, public and private, along the coast of Washington and Oregon.*

One of the most damaging dune areas is located near Warrenton in Clatsop County, Oreg. North of this dune area the Columbia River empties huge quantities of sand into the Pacific. Moved about by ocean currents, much of this sand eventually is swept up on beaches, which extend to the south unbrokenly for 30 miles. Here the properties which lie before the advancing dunes are exceptionally valuable. In order to save these properties from being enveloped in sand, and to demonstrate measures of control which may be applied generally in the Pacific coast dune areas, the Soil Conservation Service established a demonstration project in Clatsop County in 1935.

FIGURE 28.—*As a first step to control drifting sands with vegetation, dune-stilling grasses are planted to the landward side of an artifically created fore dune.*

To explain the control measures being employed requires a backward look at the land-use history of the coastal area of Clatsop County. The settlers of two generations ago were aware of the unstable nature of the sand lying below the thin mantle of soil that covered the area almost to the tide line. As soon as Clatsop County was incorporated, in the late 1860's, an ordinance was passed prohibiting the grazing of all land west of Neacoxie Creek, a narrow body of fresh water extending parallel to the coast for a distance, then abruptly turning and emptying into the sea. For almost 40 years the ordinance was respected; a few offenders, at first, were heavily fined. But new people came into the area. They ignored the ordinance, subdivided the land, and brought cattle to graze. Close grazing soon killed the grass, exposing the sand to the wind. The sands piled into dunes that rolled landward before the high winds which sweep the area.

The problem is to stabilize the dunes by reestablishing vegetation over the entire sand-covered area.

Paradoxically, the first step in stopping the advance of the dunes is to build a dune artificially. This man-created fore dune is built parallel to the coast as close to high-tide line as possible. Its purpose is to break the sweep of the ocean winds as they lash inland. A double-line picket fence is driven into the sand where the dune is to be formed. The incoming sands pile over the fence. Each time the picket stakes are covered they are pulled up half their length. This is repeated until the dune attains a height of 8 or 10 feet. The dune is then planted to sand-stilling and sand-catching grasses, such as Holland and American dunegrasses. The vegetation collects more sand, and the dune gradually rises to its ultimate height of 20 or 30 feet.

Dunegrasses behave peculiarly. For example, Holland grass survives only on barren, moving sand. When organic matter accumulates or when the sands cease to move, it dies out. Even on comparatively still sand the plant loses the bright-green coloring which is its characteristic when growing on mobile sand. Dunegrasses seem to resist any amount of adversity. In the fall of 1935, C. C. C. boys working under the direction of the Soil Conservation Service, planted to Holland grass an area 100 feet wide and 8,000 feet long adjacent to the high-tide mark. Two weeks afterwards a storm whipped up enough sand to cover the new planting 20 inches. Before the winter ended storms piled on 10 inches more. Yet the followng June, 95 percent of the plants had survived.

A second control step, which is carried on concurrently with the dune building, is the planting of dunegrass species at 18-inch intervals (fig. 28) over the blowing areas to the landward side for the fore dune. Later, as a third step, sod-forming and soil-building vegetation is established; and finally in those areas that will support such vegetation, trees and shrubs are planted for further protection. The nature of the permanent vegetation is not yet determined with finality. Various species of native and imported grasses and shrubs are on trial, and the most promising of these will be selected to succeed the dunegrasses.

Flood Control on the Hillside

IN THE UPLANDS, where floods form, nature works to prevent violent off-flowage of water by throwing a blanket of vegetation over the land. Each leaf, each blade of grass, each tangle of roots is a miniature dam holding its share of raindrops. Each burrow and each soil crevice opened by a root is a tiny subterranean channel giving free entrance to subsurface levels. Streams whose head-waters reach into well-forested or grass-covered watersheds seldom overflow their banks and then if they do, it is usually without destructive violence.

Land denuded of its vegetation is like a tin roof. It delivers water to a creek as a tin roof delivers water to a downspout. Streams fed from denuded water-sheds overflow their banks frequently. After violent storms they rage. Soil slips and slides, and torrents transport soil and rock. Streams fill with debris and cut new channels. Valley properties decline in value. Populations are endangered. Life is lost.

The Soil Conservation Service believes that floods will become less frequent and far less destructive when these denuded watersheds are again protected by a cover of vegetation. To demonstrate methods, two watersheds were chosen for demonstration projects, one a watershed of range land, the other a watershed of forest which has suffered from overgrazing and fire damage.

At Pocatello, Idaho

For years the city of Pocatello, in southeastern Idaho, has suffered from floods. Pocatello nestles in the valley of the Portneuf River; but the river is not the source of the city's flood troubles. Water and rock and silt come down upon the city from above, from great gullies in range land rising on each side of the river.

The range around Pocatello, in common with most of the range in southern Idaho, is severely overgrazed. The Portneuf Valley, however, is more severely eroded than most of the surrounding range. About 100,000 sheep trailing through the valley twice a year, from winter feeding grounds to summer range and back, have damaged the cover. The slopes above the city originally were covered with bunchgrasses and associated species. In the draws were a few firs, junipers, and trees of other species. In passing through, the sheep grazed the perennial grasses to their roots year after year. The perennial grasses produced no seed, the plants declined in vigor, and died out, displaced by cheat and weeds of little value in holding soil and water.

The district around Pocatello is subject to summer storms of cloudburst proportions. "Waterspouts", as these storms are called locally, occur from time to time. Three struck in the summer of 1936. These torrential summer rains cause the most damage, although each spring, when the snows melt rapidly, the city is visited by a flood.

The only known means of alleviating the flood hazard to the city is to control the flood waters at their source—to hold the raindrop where it falls, on the hillside. To accomplish this a camp of C. C. C. boys, under the direction of the Soil Conservation Service, is at work on the 12,000-acre watershed above the city, building contour furrows (fig. 29) and preparing the soil for reseeding to

FIGURE 29.—*The flood hazard to the city of Pocatello, Idaho, is alleviated by building contour furrows on the hillsides of the watershed. This is a first step in revegetating the denuded area that deluges the city with water, silt, and rock during cloudbursts.*

adaptable grasses. The purpose of the contour furrows is to hold the water until the watershed becomes revegetated with native grasses. After that, vegetation becomes the first line of defense.

Furrows are built on the exact contour of the slopes. They are plowed out in the rough and finished by hand by C. C. C. boys. The furrows, about 15 to 18 inches deep and about 30 inches across at the top, are spaced closely enough to catch all of the run-off from storms of maximum expected intensity.

On July 31, 1936, a cloudburst struck the area; more than an inch of rain fell within 30 minutes. That part of the watershed protected by terraces delivered no water into the city. From the part not yet furrowed a great deluge found its way to the city and caused great damage.

The hillside furrows conserve moisture, which stimulates the growth of the better soil-conserving perennial grasses. The ridges themselves are seeded to

a mixture of native grasses, a little sweetclover and Ladak alfalfa. Within a few years the grass is expected to spread from ridge to ridge, providing flood protection so long as stock is excluded. [2]

Stockmen have agreed to trail their sheep around the watershed, and the whole of the area is being fenced for further protection.

Other cities in the Pacific Northwest face a similar problem. The Pocatello project demonstrates a practical means of dealing with such floods.

At Cashmere, Wash.

From the foothills of the Wenatchee Range to the Wenatchee River the banks of Mission Creek are skirted by orchards. Orchards in the valley are valued at $400 to $1,000 an acre. Periodically, floods rage through the valley,

FIGURE 30.—*Periodically, Misson Creek rises in flood, sometimes tearing out blocks of trees and covering other valuable orchard land with sand and gravel.*

sometimes cutting deeply into the banks of the stream, tearing out blocks of trees (fig. 30), and covering other valuable acres with sand and gravel.

Mission Creek drains a watershed of 150,000 acres. Its headwaters lie in rough, broken stony land, a part of the Wenatchee Range. The underlying

[2] In project areas in which the problem to be met is specialized, that is, deals primarily with flood control, protection from mobile sands, or conservation of water for irrigation purposes, rather than with soil conservation directly, livestock are sometimes excluded, or their numbers are drastically reduced. This statement, therefore, and others like it, is not to be construed as reflecting the range-management recommendations of the Soil Conservation Service. Such recommendations are set forth in the section headed "In Defense of the Range."

rock is sandstone steeply tilted and covered by a thin mantle of sandy or sandy loam soil. The soil on the south and west slopes, owing to the tilting of the rock, is shallow. Vegetation, consequently, is sparse. In many places sandstone lies exposed. A thicker soil mantle covers the north and east slopes, except where burning or overgrazing has depleted the cover and encouraged erosion.

Following a flood in 1933, timber and stone facings were built along the stream banks in the lower valley, but these promise only temporary protection. Revegetation of headwater slopes alone promises permanent relief.

To revegetate some of the slopes is difficult, because much of the soil has been lost and bare rock lies exposed on part of the watershed. The program calls for building water spreaders to divert water from the bald spots to vegetated areas, where it will penetrate into the soil. Water spreaders are embankments of earth seeded to a mixture of adapted grasses. They are protected temporarily by dams of hog wire and posts covered with burlap dipped in a preservative.

The upland open and sparsely forested range is being contour furrowed, planted to trees, and fenced to prevent cattle from browsing on the seedlings. The principal tree species planted are yellow pine, caragana, desert ash, green ash, black locust, and western hackberry.

The forested area is protected from fire by disposing of slash and removing snags in the burned-over area. Grazing, by contract with the landowners, is restricted in all of the watershed.

Conserving Irrigation Waters

IN SOME OF THE irrigated areas in the intermountain zone of the Pacific Northwest the supply of water in some years is inadequate for profitable crop production. Particularly is this true of those areas that depend upon smaller streams for their water. Most of these streams are spring-fed. In midsummer the springs falter or cease to flow, and crops on irrigated lands in the valleys below suffer for want of water.

Measures employed to lessen washing of the surface soil also stimulate the flow of springs; for the basic principle underlying all measures to prevent soil washing is to direct water into the soil by preparing the soil to absorb it. The water enters a reservoir of ground water which supports plants and feeds springs and mountain streams during dry-weather periods. On the other hand, water that runs over the surface of the soil, causing soil washing, adds to stream-flow peaks in wet-weather periods when water is not needed for irrigation purposes.

An example is Ahtanum Creek, which supplies water for irrigating the upper valley of the Yakima. Each year in late July and August the creek shrivels almost to a trickle, and about 35,000 acres of orchard suffer for water during the period it is needed to size the fruit. The watershed of Ahtanum Creek is a soil- and water-conservation demonstration project of the Soil Conservation Service.

The three principal forces that impair the cover of the watershed and lower its water storage value, are fire, overgrazing, and logging.

The program now being effected calls for cessation of overgrazing, improved cutting and logging practices, protection from fire, replanting and reseeding of areas on which the cover is most seriously depleted, and the use of some mechanical measures to check water run-off.

In the first year in the progress of the demonstration the number of stock permitted to graze over the 32,000 acres in the watershed was reduced from 6,500 head to about 600 or 700 head. Drift fences have been constructed to protect the small cover from too early grazing in the spring, that seed might be produced and perennial plants make sufficiently strong root growth to multiply. To aid further in distributing grazing properly by season and according to forage readiness, a salting plan was introduced which attracts the cattle, as the season advances, from overgrazed to undergrazed areas. These plans are carried out in cooperation with the State and private operators, who control the use of the land.

Roads and trails are being improved to open the forest to ready access in case of fire. Snags, always a fire hazard, are being removed from burned-over areas. The whole of the watershed is watched over by forest rangers.

C. C. C. boys, working with the Service, are planting trees on denuded areas, in contour furrows. Wherever overgrazing has severely impaired the cover it is necessary to furrow, reseed, and fence the range. Within a year after the first furrows were made, vegetation noticeably thickened, and perennial types of plants became more prominent in the cover.

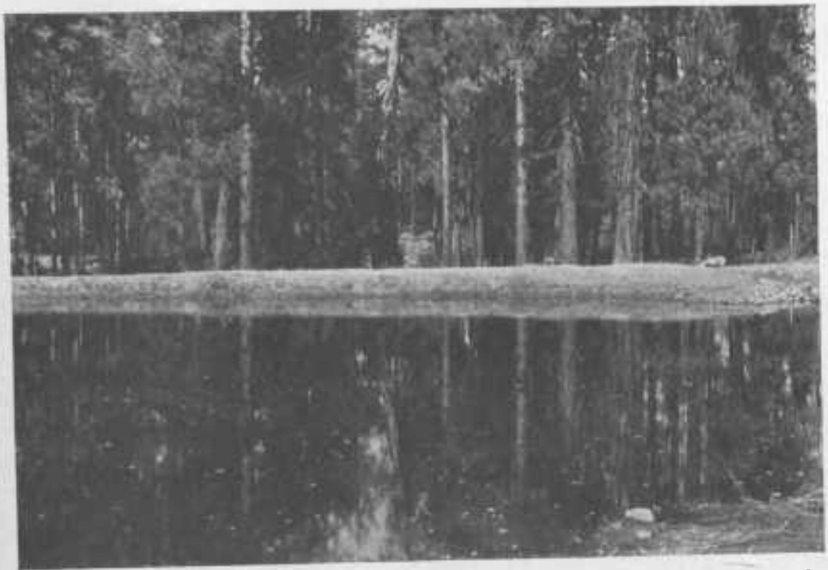


FIGURE 31.—*To preserve water for irrigation purposes, earthen dams are built across intermittent streams draining into Ahtanum Creek, to provide a more continuous supply of water for orchards in the upper Yakima Valley.*

Ditches are built to catch water from rock slides and divert it to vegetated areas, where it may seep into the soil.

The program calls for building about 50 earthen dams (fig. 31) across intermittent streams in the watershed, to pond water during the period of rapid run-off in the spring. These dams are built on natural sites, and hold, when full, from 1 to 15 acre-feet of water.

In this area one or more water-conservation measures are being used on practically every acre of the watershed.

U. S. GOVERNMENT PRINTING OFFICE: 1937

For sale by the Superintendent of Documents, Washington, D. C. . . . . Price 10 cents